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LIGHTING IN THE INDUSTRIES*

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WITHIN the past half century or less, two marked tendencies have appeared in our urban life which are no doubt due to the progress that has been made within that time in the practice of artificial lighting. One of these is the general turning of night into day, not only for our play but for our work on the night shift. The other is the rapid increase in the height and compactness of our buildings—not only our industrial and commercial buildings but our modern houses of living apartments as well.

Such intensive utilization of the original ground space as we now see would scarcely have been possible without adequate means of artificial lighting to fall back on when the natural source of light is excluded by reason of the inadequacy or the absence of outside openings. The tremendously increased use of artificial light which has taken place within these few decades has naturally opened up many questions as to the effect that its general use might be having on the human organism. Some of these questions seem to have been adequately disposed of, while others are still under discussion.

Among the former we might mention the questions that have arisen regarding the character of the light that comes from our modern artificial light sources. As the kerosene and gas flames were being replaced by the incandescent filament, and the filament, owing to progressive improvement, was being operated at higher and higher temperatures, it became a question well worth considering whether these white-hot threads were emitting rays of some sort or other which might be harmful to us. If so, it was high

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time that we should know it. Investigation has, however, failed to show that the heated filament emits anything that is not contained in ordinary sunlight; and measurements have shown, too, that the sunlight, to which man has undergone prolonged exposure in the course of his many centuries of evolutionary growth, is of an intensity hundreds to thousands of times as great as any artificial intensity contemplated.

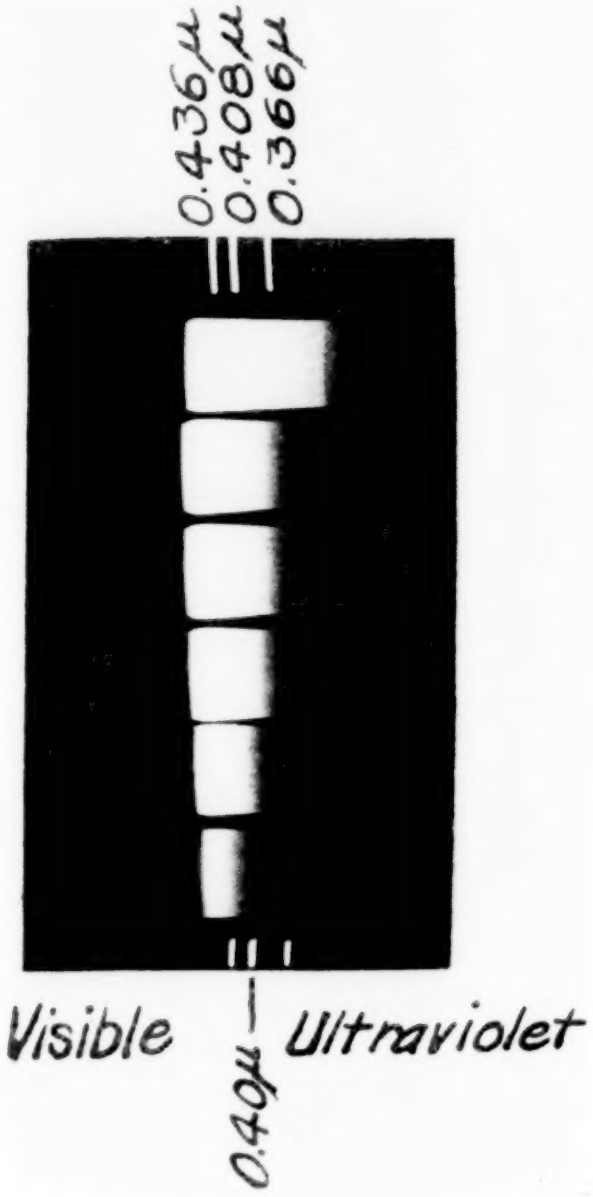
The light that makes things visible to us is a small range within a long scale of waves, spoken of sometimes as electromagnetic waves, and sometimes simply as radiation. These radiations differ from each other in wave length (or frequency) but in no other fundamental particular. The "visible" waves range from the extreme violet of the rainbow or spectrum, having a wave length of about 390 mμ (millimicrons, or millionths of a millimeter), to the extreme red of perhaps 760 mμ— or about one octave, by analogy with the musical scale. Below the former, for a limited distance, lie the shorter ultraviolet or so-called "chemical" rays, extending to 290 mμ in the case of solar radiation and skylight and to much shorter wave lengths in the case of electric sparks and arcs enclosed in quartz or unenclosed. Ordinary glass is quite opaque beyond 300 mμ, and most glass absorbs strongly in the region between 300 mμ and 350 mμ. Beyond the red, from 760 mμ on, lie the infra-red or so-called "heat" rays. The continuity of the series has already been established far beyond the limits stated, and the X-rays have been shown to be of identical character but of extremely short wave length; while the hertzian waves are of much longer wave length than the infra-red, extending up to hundreds and thousands of meters in length.

These waves all travel with the same velocity, which is, of course, the velocity of light, about three hundred million meters per second. Anyone who wishes to know the frequency of any particular wave length may have a surprise by calculating it. It will be, per second, the number of wave lengths that will lie, end to end, within that distance. For light of 500 mμ wave length, which is not far from the middle of the visible range, this number is six hundred trillion per second.

Those rays which have been thought to be pernicious to the eyes, under the usual conditions of modern lighting, are the ultraviolet. While certain troublesome disturbances, especially in the eyes, are known to result from ultraviolet rays, it is fortunate that up to the present time no material has been found for making lamp filaments that will withstand the temperatures necessary to produce these rays in more than very small amounts (see Fig. 1), and furthermore, the glass globe that must surround the filament is an effective barrier against the passage of waves short enough to do damage. Indeed the case is quite the other way with the modern lamp filament. At the highest practicable temperatures the excess of radiation is at the long-wave end of the spectrum, in the red and infra-red. It is doubtful if these waves are capable of harm other than by their mere heating effect, and this is initially a painful stimulus which leads the person exposed to protect himself at once.

J. I. H.
May, 1925

It is common to conclude that an unusual circumstance is the cause of an unusual fact. The assignment of modern light and lighting as the cause of the present high incidence of eye troubles, and consequently of the extensive activity of the manufacturing optician, is a case in point. It is pertinent here to ask the question whether or not there actually is more eye trouble now than there was a generation or so ago; or whether the demands upon our eyes made by modern civilization, especially in our cities, have simply brought to light such defects as already existed, but which are no more frequent now than in the decades gone by when they more easily went undetected. We who are concerned with lighting problems long ago concluded that artificial light is in itself pernicious only when misused; that is, when insufficient, or when applied in the wrong place.



Source	*Relative Photometric Intensity*
Daylight (sky)	1
Tungsten lamp	10
Tungsten lamp	8
Tungsten lamp	4
Tungsten lamp	2
Tungsten lamp	1

FIG. 1.—Short-wave spectra of daylight from the sky and from tungsten filament lamp, for equal photographic exposures and various photometric intensities. The full extent of the visible spectrum is not shown owing to the insensitivity of the plate for those wave lengths.

The lighting question has as many phases as any other circumstance in our surroundings. There are some fifty thousand blind persons in this country, and lighting is a matter of the highest importance to at least the

remaining one hundred and five millions.

There are two phases to be considered with reference to the use of light, as with respect to any other of our surrounding conditions. One is its effect on our individual welfare; the other, its effect on our usefulness as productive members of the community. When we come to consider these in detail, we find that they are more or less interrelated; that, in fact, our usefulness to ourselves and our usefulness to the group within which we are units are not far from identical.

The personal welfare of the individual has several aspects with reference to the lighting, not only of the actual workplaces, but also of the other places about the plant where he must go. The lighting of the work must be such as not to impair his health. Here, of course, his vision is of the highest interest. Further, the lighting of other parts of the works has to be considered; in relation, first, to general sanitation. Dark places are apt to be neglected in cleaning and become dirty. Good light in toilet rooms gives an opportunity, at least, to avoid chances for infection of various sorts. And finally, but of no minor importance in the matter of the health of the individual, we must consider such intangible "mental" influences as comfort and the maintenance of good spirits generally.

In a somewhat different class is the contribution that light can make to safety. Obviously, relative freedom from accidents can be achieved by the adequate lighting of corridors, stairways, and the various necessary danger points in and about the works. Warning signs are of no avail without sufficient light to make them legible, which is to say nothing of the lighting of the actual situations themselves.

It should not require argument to show that such conditions as favor the welfare of the individual worker, good lighting for instance, must necessarily react to the advantage of the business. The saving of the time of an experienced employee, lost through preventable accident or illness, is the most obvious case in point. Similarly, conditions which make the work possible with less bodily strain, for example, eyestrain, can hardly result otherwise than in increased output of work, by making unnecessary the frequent cessations or relaxations that constitute, in the aggregate, no insignificant fraction of the time that appears on the payroll.

Over and above the considerations just enumerated, we will all probably have to admit, sooner or later, that even such apparently irrelevant things as the personal comfort of the workers, and their general cheerfulness, good spirits, buoyancy or feeling of well-being—or whatever we may choose to call it—will lighten their efforts and make possible the same work with less expenditure of time and strength, or more effective work in the same time without corresponding increase in the fatigue and bodily wear and tear. The avoidance of glare, caused by an undue amount of light directly from the lighting units entering the eyes of the workers, is important for comfort as well as for efficient vision and freedom from eyestrain; and a pleasant outlook on the worker's surroundings makes for cheerfulness and willingness. It is not expected that the inside of

the factory will ever come to look like the interior of a palace, but at least the avoidance of ugliness can be aimed at, even if positive beauty of environment cannot be attained. This may be done by attention to the paint on the walls and the ceilings, to the other elements of interior finish, and to the disposition of fixtures and movables which have to be in sight. Attention to the amount and distribution of the light falling upon these things follows as a matter of course, in consequence of the obvious and much neglected fact that the appearance of all things to the eyes depends entirely on the lighting of them, and is nothing at all without it. The cost of such improvements may be charged to welfare; but a subsequent comparison of output with payroll may make this unnecessary.

It will be noticed that in the foregoing discussion fundamentals have been treated which are quite general to the subject of industrial hygiene, which are at the present time of increasing importance in factory management, and which are receiving consideration from many points of view other than that of lighting. These fundamental considerations are: the safety, health, comfort, and general mental well-being of the producing workers. It has been the especial object here to emphasize how, by proper attention to the lighting, these may be furthered and, moreover, to indicate that properly designed lighting improvements may be expected to justify themselves not only from the standpoint of humane sentiment but also from the standpoint of business.

With respect to the efficiency of the worker these may be designated as the indirect advantages of good lighting. There has been a body of evidence collected, however, to show in a striking way that good lighting has a very direct result in production. Such evidence is of two types: first, the statistical study of the actual output of groups of operatives under different systems of lighting; and second, the analytic study of the process of vision in the laboratory with respect to light intensities and distributions on the one hand, and the time consumed in the various phases of the physiologic process of vision on the other. To these might perhaps be added a third—the intermediate procedure of measuring the gross time of some visually controlled operation, such as reading, in the laboratory.

Of the over-all production tests in the factory we may here cite one (1). This test was performed in a factory in Ohio. The work, done by a group of operatives who acted as subjects, consisted in the inspection of various steel parts of roller bearings, examining them for defects in the material and for imperfections in the machine work which had been done on them. This was all a part of the routine factory work. The subjects were not informed that any test was being run, and the experimental records of the work done were taken from the regular factory records. The final results are stated as the average number of pieces inspected per person per hour, and they represent work extending over a period of ten weeks. The first two weeks the "old" lighting system was used which gave about 5 foot candles including a certain amount of daylight. This was then permanently abandoned in favor of three well-designed test systems, giving respectively 6, 13, and

20 foot candles on the work tables. These were used in irregular order, each a week at a time.

The results yielded averaged for the old system, 5 foot candles, 407 pieces inspected per hour. The results for the new system averaged: 6 foot candles, 424 pieces; 13 foot candles, 440 pieces; and 20 foot candles, 458 pieces. The increased production which accrued to the business from these results amounted to 4, 8, and 12.5 per cent. of the payroll respectively, since the workers were paid on the hourly basis. For the four lighting systems, the cost of current and lamp renewals was estimated as 0.3, 0.8, 1.6, and 2.4 per cent. of the payroll respectively; that is, for any one of the three "new" systems of lighting, not over one-fifth of the correspondingly increased effectiveness of the payroll. This comparison is shown graphically in Figure 2, taken from a recent book by M. Luckiesh (2) which summarizes and discusses a large amount of material relevant to the subject of this paper. It will be noticed that even at 20 foot candles there is no indication of diminishing returns, and one is tempted to ask what will happen at even higher illuminations. It would seem that in providing better lighting we are shaving down the time lost in the visual process, which cannot itself be more than a fraction of the total time and which becomes a less significant part of the whole the more it is reduced. Thus a diminishing advantage is to be expected at some point or other. But since, in this case, the increased production at 20 foot candles is sufficient to pay for 100 foot candles, it is safe to say that the same experiment conducted anywhere between these limits would entail no monetary loss.

So much for the efficiency aspect of these tests. It is time to examine them from the aspect of hygiene. To most illuminating engineers it is an unheard-of and preposterous thing to propose 100 foot candles as a practical thing. It has been difficult to get factory management to consent to as much as 20. The cost appears unjustifiable and prohibitive. From other quarters come other adverse arguments. The intensity of the light will ruin the eyes of the workers. The intense light acts as a stimulant and whips up the workers to a grade of activity that will wear them out. And a very real question to be solved in this connection is that of the heat. For equal visual effect our artificial lights are much stronger in the long-waved (red and infra-red) energy than is sunlight, so that at increasing intensities their heating effect will sooner or later become a serious problem.

We have, however, seen the cost of the light justify itself, and engineering can take care of the heat for some time to come. But what about the terrible effects on the eyes of the worker? And the ruinous effect of stimulating him by a flood of light having the enormous intensity of 100 foot candles?

A glimpse into the history of lighting will perhaps explain how such views have come to be held. The old-fashioned candle has a luminous intensity of about 1 international candle, and gives an illumination of 1 foot candle at a distance of 1 foot. A yard away it yields one-ninth of this. Later, with the advent of oil lamps, kerosene, gas, and electricity, the illuminations in use naturally rose as the

means became available without excessive cost. Until quite recently 5 to 10 foot candles were considered high intensities to use in artificial lighting practice. Today, as may have been gathered, 20 foot candles are being practically used, but are, perhaps, not yet beyond the experimental stage.

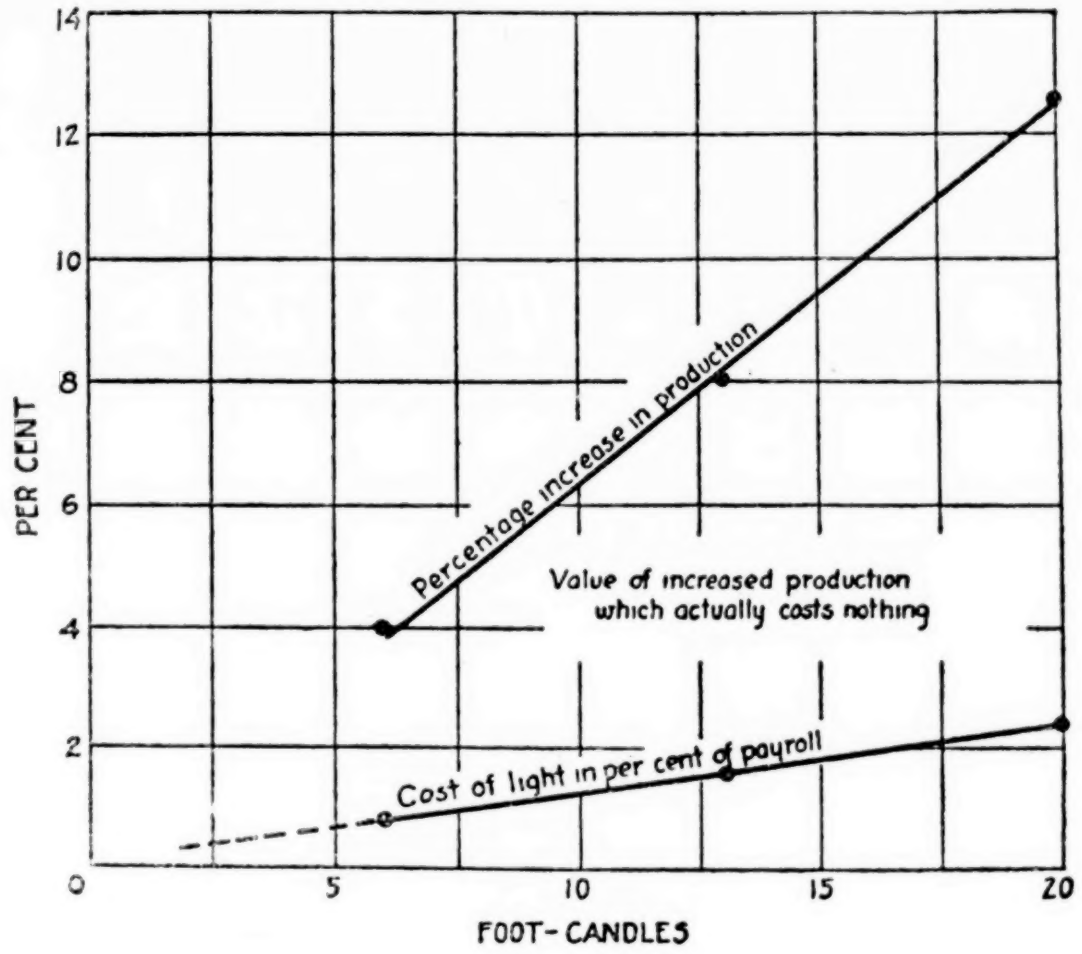


FIG. 2.—Increase in production due to improved lighting and increased illumination, compared with the cost of the same. Data of Hess and Harrison.

On the other hand, the sunlight, under which human eyes have worked and evolved for centuries, rises as high as 10,000 foot candles in moderate latitudes, and it is a despiritingly dark day indeed when the illumination under the overcast sky in the open does not exceed 500 foot candles. Would one think for a moment in going out into a gray day into the illumination of 500 foot candles that he was in danger of injuring his eyes by exposing them to this "terrific" energy? Would he expect to be overstimulated into shoveling the snow off the front walk with such energy that a rest cure would be necessary? The fact seems to be that few lighting experts have given enough attention to daylight to be alive to these facts concerning its usual out-of-door intensity. Their concern has been to furnish artificial light, of which the candle is the prototype and the unit; and to keep the cost down. The result has been that intensities of artificial light have been thought of only in themselves, and not in terms of the daylight intensities commonly encountered and accepted by human eyes for centuries. Conservatism is a natural resistance to innovation and has no doubt frequently been an effective protection to the human race

against radical changes of dubious or negative value. Nevertheless, even when it is to be respected, its defenses are often plausible rather than in accord with the known facts.

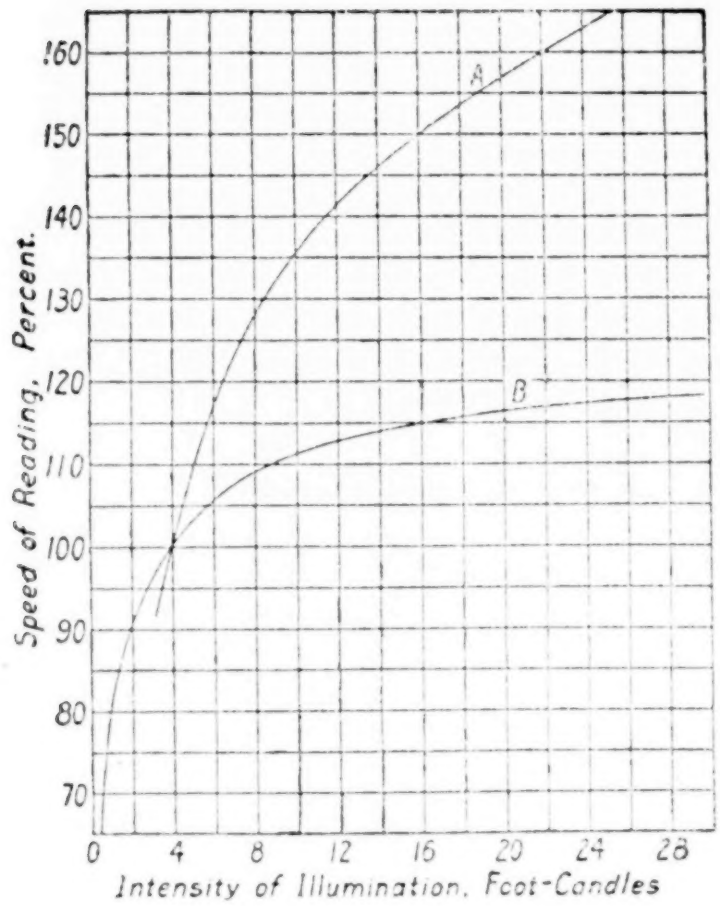


FIG. 3.—Comparative speed of reading for a group of subjects. A, Old English text, black letters on a ground having 23 per cent. reflection factor. B, the same on a white ground having about 80 per cent. reflection factor. The two sets of values have been arbitrarily represented as 100 at 4 foot candles, to show the relatively greater increase in speed for the more difficult object, A.

It will be profitable now to turn from the factory tests, such as have just been described, to some of the results which have been attained in the laboratory. The nearest comparison to be made is with some results on the speed of reading (3). In this experiment, columns of reading matter were mounted on a slowly rotating drum and viewed by the subject. The text was covered, except for a very few lines, and the subject was required to adjust the speed of rotation of the drum so that it tallied with the rate at which he could read the text aloud. The text was in Old English type, reproduced photographically to give, A (Fig. 3), black letters on a gray background having a reflection factor of 23 per cent., and, B, black letters on a white background, the reflection factor being 80 per cent. The speed of the drum for each trial with a number of different illuminations was read from a speedometer attached to the drum and a number of subjects were used.

Naturally, the speed of reading A was lower at every point than for B. However, the relative gains with increasing illumination are shown in the figure, where in each case (A and B) the speed at 4 foot candles was put at 100 per cent. The outstanding point is that with an object more difficult to see, in this case owing to the low contrast between type and paper, a proportionately larger gain is found with an equal increase in the amount of light. This general fact will appear again later.

It has been of interest to turn from these facts, which are the over-all results of timing complete physiologic operations, and ask ourselves questions as to *how* this shortening of the time comes about. To begin to answer these, we are obliged to analyze, as far as we can, the physiologic operations concerned.

The "work" done by the experimental subject, whether in the factory or in the laboratory, is in every case a series of muscular reactions some of which (more or less, in different kinds of work) are of necessity visually con-

trolled. Nearly all of our activities, ordinary or otherwise, are more or less under the control of vision. We would not get far with them in the dark, nor with our eyes closed. And yet, within our total activity there are many periods of time, longer or shorter, during which we could get on equally well with our eyes closed. Such times, in the aggregate, can be subtracted from the total as not relevant to lighting. In such tests as have just been described, and by reason of the method selected, they constitute a dead fraction of the time considered, which contains no activity that can conceivably be either delayed or hastened by any change in the lighting.

The visually controlled reaction, stripped of as many complications as possible, figures in the reaction-time experiment of the psychologic laboratory. The subject has presented to him, let us say, one of not less than two different visual objects, *a* and *b*, of as nearly equal difficulty for vision as possible; and he responds to it by speech, or some other movement, in a way that must be appropriate to the object according to some prearranged plan—*e.g.*, he presses a key under his right hand for *a*, one under his left for *b*. The time that elapses between the presentation of the object, *a* or *b*, and his response to it is measured and constitutes the reaction time for that particular case.

It is not the purpose at present to discuss the niceties of reaction-time measurement, nor to discuss the implications of the results, once a large number of them have been made and statistically tabulated. Suffice it to say here that the reaction of a subject as just described is a visually controlled reaction, of a type that has purposely been made as simple and as free from complications as possible. A certain clarity has thereby been gained, at the expense of the fact that such a reaction is to a certain extent removed from its place in the totality of human activity.

In the light of physiology as at present understood, a simple reaction of this sort may be analyzed into not less than three parts, the division being due to the limitations of our experimental methods arising out of the situation itself. There is, first, the impact on the sensitive end-organs of the retina of the light from the visual object and the ensuing neural impulse traveling the optic nerve to the brain; and, third, the neural impulse traveling outward, finally from the spinal cord, and initiating the muscular contractions which constitute the response. The second segment of the reaction, intermediate in time between these two, is the poorly understood and probably highly complex[1] activity in the central nervous system which determines the linkage between these two and conditions the appropriateness, or otherwise, of the response to the stimulus.

Much of the complexity inherent in this total process may be avoided if we limit our attention to the very first part of this train of events and

[1] The complexity of such a simplified reaction is not lessened by the fact that its removal from the total of the subject's activity can never be complete. That is, in addition to the principal stimulus and the principal reaction which it is designed to study, the organism is subject to (1) other objects acting upon the sense organs during and also prior to the time of experiment, which tend to set up (2) reactions other than the one which it is proposed to study.

study the time that elapses, beginning with the very first impact of light on the retina and ending when the resulting neural disturbance in the end-organs reaches a grade which is adequate to determine the response. Over and above the relative simplicity of the event that it is proposed to study here is the advantage that this is the portion of the whole reaction time that may most reasonably be expected to show consistent variations with such things as the character and amount of light falling on the visual object, and with the light distribution. The experimental technic involved is not difficult to describe. A test object is provided which can be abruptly exposed and abruptly cut off, with auxiliary devices to control and measure duration of exposure. By trial, the duration of exposure is found which is the threshold for appropriate response.

A number of pieces of laboratory research have been carried out, using methods essentially of this description (4) (5), the ultimate object in view being knowledge of the effect of illumination conditions on the rate at which work can be done. As is usual in this sort of work, rather wide differences have been found between individuals. On the other hand, the changes with changes in the illumination have been found generally consistent, and it is to the latter especially that attention is to be called.

What has been found almost without exception is that the necessary time of exposure of the test object is shortened by increase in the intensity of the light, other things being equal. That is, the "speed of vision"[2] (unity divided by the time of exposure) has been increased, and this continued as far as the experiments have been carried, up to about 100 foot candles. The one exception found is that of a test object of such character and of such large dimensions (curve I, Figs. 4 and 5) that it is no longer critical for vision. For this test object the time was not reduced by increase in the illumination beyond about 40 foot candles.

The test object in this case consisted of two parallel black rectangles (*b*, Fig. 6) on a white ground. This could be shown in either the vertical or the horizontal position, and was preceded and followed by patterns *a* and *c*, presented in such a way that the three were successively centered at the same point in the visual field. The time given is that during which the test object *b* is exposed. In the case of curve I, Figures 4 and 5, the width of the bars was 6.35 mm., representing a visual angle of 3.64 minutes.

With a test object of one-half these dimensions (3.18 mm., subtending a visual angle of 1.82 minutes) a different result appeared, the time was longer (lower "speed"), as might be expected, but it did not appear even up to 100 foot candles that a limit had been reached. The appearance of the curve (II, Fig. 5) does, however, show some indication that an optimum might be reached if the experiment were to be carried to still higher brightness levels.

Removal of the confusion fields *a* and *c*, Figure 6, gave the result shown in curve III, which is to be compared

[2] The terms "speed of vision" and "speed" in this connection are perhaps misleading when applied to a quantity which, as will appear, has no practical meaning but only the mathematical significance stated.

with curve II, since the test object itself (*b*) was of identical size in the two cases. Incidentally, when the reciprocal of the time is plotted against the logarithm of the brightness, as in Figure 5, this relation appears as a nearly straight line, which makes it possible to express the relation in this particular case, within the limits given, by means of a fairly simple mathematical formulation, should one care to do so.

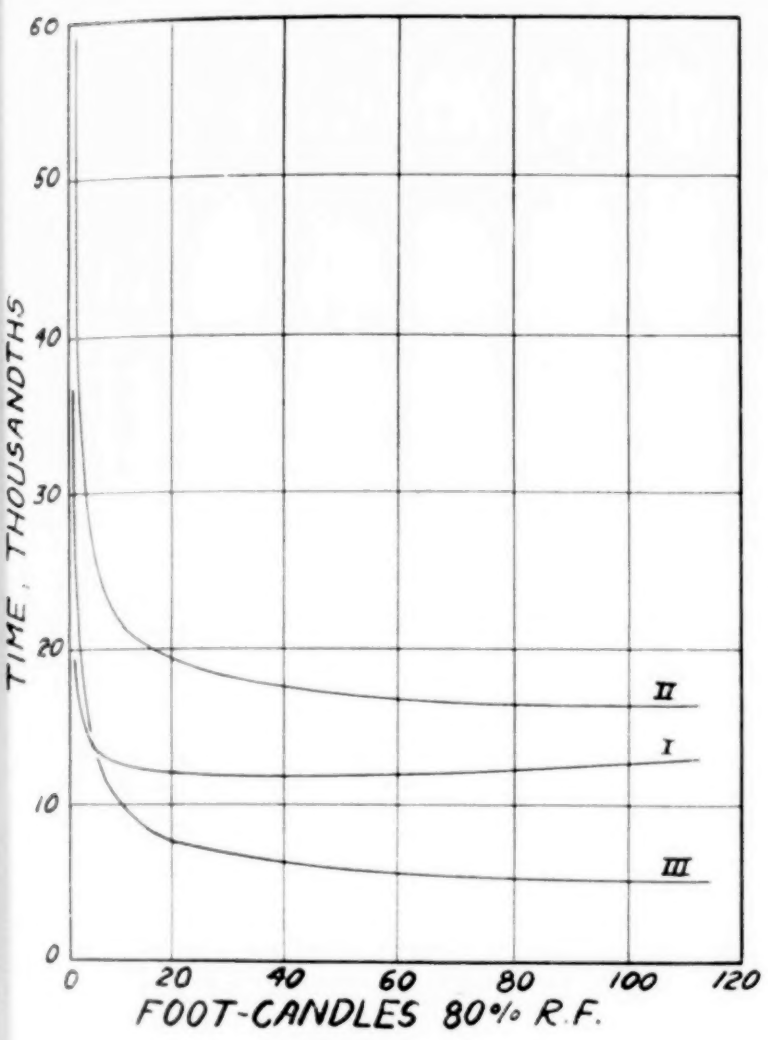


FIG. 4.—The threshold times of exposure of a test object for various conditions, and for brightnesses of ground equivalent to the various illuminations given, upon a diffusing surface of 80 per cent. reflection factor.

I.—Smallest dimension of test object 6.35 mm., which subtends a visual angle of 3.64 minutes at the subject's eyes, 6 meters away. Confusion preexposure and postexposure patterns used (*a*, *b*, *c*, Fig. 6).

II.—Test object reduced in size to one-half: 3.18 mm., subtending a visual angle of 1.82 minutes. Otherwise the same as I.

III.—Same as II, but *a* and *c* (Fig. 6) omitted with the result that *b* rose out of an unbroken field equal in brightness to its ground.

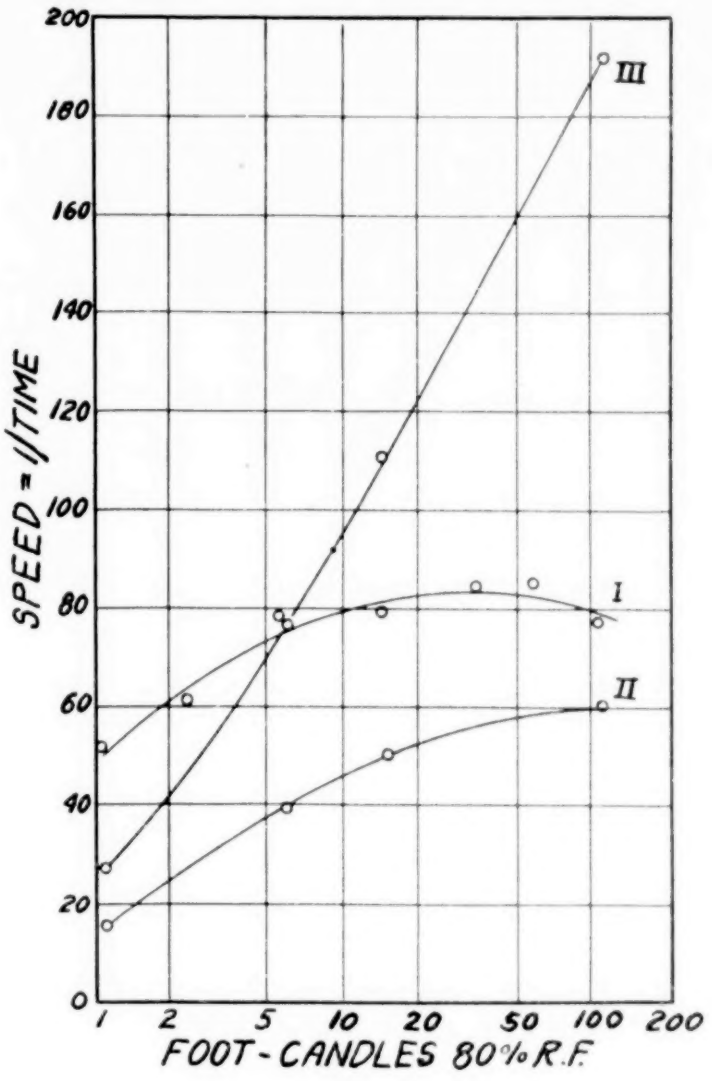


FIG. 5.—The same data as Figure 4, plotted as "speed" (reciprocal of the time) against the logarithms of the corresponding illuminations. The small circles show the original data.

I, II, and III.—The same as in Figure 4.

that the test object was invariably seen on a white background of approximately 80 per cent. reflection factor, which is such that 1.16 foot candles were required for each millilambert of brightness. For backgrounds of lower reflection factors (gray or dark) the illumination would have to be increased in inverse proportion to make the surface of the same brightness. As most of the materials on which work is done have reflection factors less than those of so-called white surfaces, and

many of them far below, it may be seen that for such cases the illumination would have to be correspondingly increased, moderately or greatly as the case may be, to make the brightness of the work equal to that of the experiment. To illustrate: In Figures 4 and 5, if we wished to estimate the results in case a dark gray test object had been used instead of white, having a reflection factor of 8 per cent. instead of 80 per cent., the foot candles should be multiplied by 10. But even then our correction is only partial, for since the ink of the test object, supposedly black, has itself a finite reflection factor, by raising the illumination we have multiplied its brightness by 10, while that of the ground has merely been kept constant. Thus a lower contrast results under the hypothetically increased illumination.

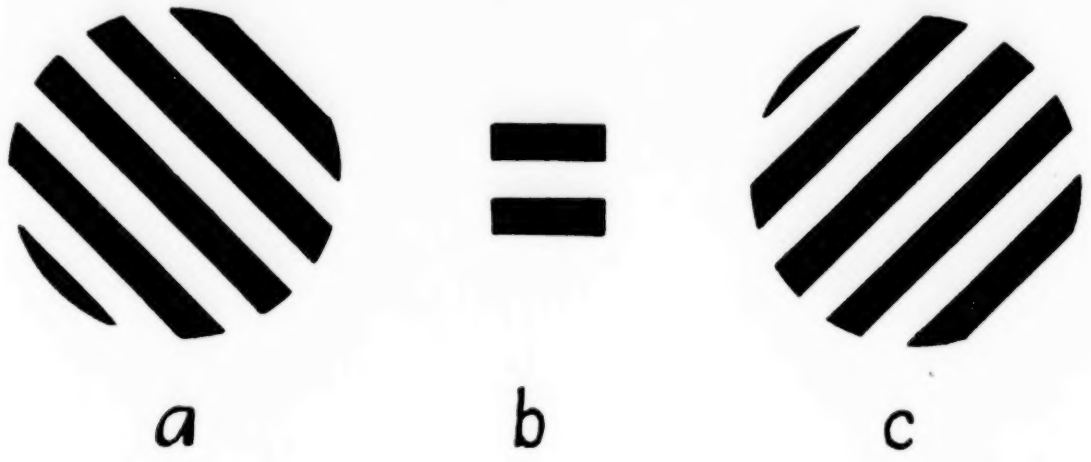


FIG. 6.—The test object referred to under Figures 4 and 5, II, actual size seen at 6 meters. The three elements, *a*, *b*, and *c*, appeared successively at the same place, *a* being in place 3 units of time, *b* 1 unit, and *c* remaining at the close. The test object proper, *b*, could be shown horizontally, as in the figure, or vertically, and the threshold time of exposure was found for appropriate response to it. In III, Figures 4 and 5, *a* and *c* were omitted.

There is a further point to be considered in the attempt to find practical application of such results as appear in Figure 5. It would be a gross error to reason from "speed" as it appears in the plot, to an equal percentage increase of production in the shop. We have already shown that the time consumed by that part of the total work which can be fairly called visually controlled reactions is only a fraction and an undetermined fraction of the whole time of work; and further, it has been shown that of a visually controlled reaction only a fraction of the time has been measured, namely, that portion of the time which can be most plausibly assumed to depend on the lighting conditions. It remains to estimate, if possible, the effect that a change in the latter may be expected to have on the over-all result; that is, on the time relations of the total physiology of production. To gain an idea of what is involved here it will be necessary to refer briefly to the eye movements.

The eyes are seldom still for more than an instant of time, and they seldom if ever move uniformly. Their movements may be compared best, perhaps, to those of an active cricket or grasshopper, and consist of quick jumps from one point in the visual

field to another, with brief pauses between jumps. While in rapid motion they are not able, of course, to receive a clear impression. The effective impression is made only during the pause, or when the image is stationary upon the retina. In actual work, this is the limited time during which the visual object can act,[3] and which corresponds closely to the time of exposure in the experiment, measured out by the laboratory apparatus external to the eye. A glance of the eyes in the shop is the exact parallel of the mechanically controlled exposure time in the laboratory. And what happens in the laboratory may be expected to happen in the shop. In any particular case, if the condition of the retina, the size, distance, and contrast of the visual object, and the illumination upon it, are such that the impression made upon the retina within the limited time is sufficient properly to control the ensuing reaction, the reaction will be appropriate. And, *per contra*, if the conditions are such that the time is inadequate, it is only by chance that the reaction may be right. This is essentially an "all or nothing" situation. The attempt to see is either successful or it is not.

Just what loss is involved in the shop by the failure to see at a glance, it is difficult to estimate. It is certainly not to be expected that it will be exactly the additional time that would be required for successful seeing. This would presuppose the retraining of the worker's eye muscles to a somewhat longer pause to suit the conditions. If this happens, and when it happens, it will perhaps be the best compromise that he can make with his conditions. On the other hand, the loss may be much greater than this, for a failure is a failure, and involves at least the time required for another trial. Over and above this, the continuity of the worker's total activity is interrupted, *i.e.*, a false movement occurs. Or, in the absence of a false movement an out and out mistake is made without interruption. Beyond this we will leave it to the imagination to estimate the loss, referable to the worker we are thinking about and referable also to the further course of production, under the headings: loss of time; exasperation; spoilage; loss of labor expended on defective material further on in the course of production; expense and loss of goodwill following the sale and delivery of the defective product.

[3] The time relations of the eye movements have been measured most accurately by photographic registration. The movements take place in about 0.04 to 0.06 seconds. The intervening fixation pauses have been found to be from 0.04 to 0.24 seconds' duration, but perhaps not effective below 0.07 to 0.1. It would seem possible, however, that in practised routine work under the most favorable lighting conditions the effective pauses may become shorter than this. More facts relevant to this point are to be desired.

Summary

In this article it has been attempted to give some idea of the minute analysis that is being made of the operation of vision, as in industry. The fundamental character of some of the laboratory work done on the way has made it, perhaps, of less direct application than practical shop tests of production, or certain laboratory tests which have the similar characteristic of measuring the overall activity. The agreement in the

results obtained by the two methods is nevertheless gratifying, and the fundamental work, in spite of its indirectness of application, points the way for further practical experiments.

The benefits of increased illumination are especially to be realized in situations where the work, by reason of the darkness of its material, or by reason of the lowered contrast or small dimensions of its critical details, is intrinsically difficult to see. This is perhaps the natural consequence of the fact that hitherto, in artificial lighting practice, economy of light has been too much emphasized. The realization of the advantages of abundant light has apparently no more than begun with the highest intensities (20 foot candles or thereabout) at present being used in some places and urged in others by the lighting engineer.

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J. I. H.
May, 1925

THE ENGINEERING-HYGIENIC ASPECTS OF DUST ELIMINATION IN MINES*

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INTRODUCTION

THE occurrence of dusts in mines confronts the mine worker and mine operator as well as all others interested in health and safety in mines with many difficult and, in some instances, contradictory and conflicting problems; and as a consequence, there are many misconceptions as to the actual effect of most mine dusts or as to remedial or alleviating measures. Moreover, much of our knowledge of the effect of underground dusts in both coal and metal mines, whether as to health or as to safety, has been gained largely during the past twenty-five years; and there has been a considerable amount of generalizing from some local condition or occurrence rather than an arrival at conclusions after extended studies and observations both in mines and in mining camps involving as many different mining localities, conditions, etc., as could be secured with reasonable expenditure of time or financial outlay.

This paper is based on approximately eight years' definite study of the effect of mine dusts on health and safety, which was made through the United States Bureau of Mines in co-operation with the United States Public Health Service, more or less directly under the writer's supervision. Intensive study was made in more than 100 coal and metal mines and mining communities in twenty-five states of the Union, and a more limited amount of underground observation was made in probably more than 100 additional mines and in their camps.

From these investigations and observations, as well as from the investigations and observations of others, it would appear that any mine dust—whether of coal or metal mine—which is insoluble or soluble with difficulty in the fluids and tissues of the respiratory organs is likely to be harmful ultimately to the health of underground workers if it is present in the air in minute form and is breathed in large quantity over large portions of the working shift. Some soluble dusts also are decidedly harmful. It appears that the quantity of dust in the air breathed more or less continuously, together with its lack of solubility, governs the hygienic harmfulness of dust to workers much more than do the specific physical or chemical qualities of the dust itself; this does not mean that air containing a large

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quantity of finely divided flint dust or similar hard, sharp, insoluble material is not likely to be more harmful than air containing a similar quantity of less inherently harmful dust such as very fine limestone dust, or coal dust, or shale dust. The breathing of comparatively small amounts of finely divided free silica or similar hard, sharp, insoluble dust is, however, likely to be much less harmful to health than the breathing of much larger amounts of less inherently harmful dust such as that from coal, shale, hematite ore, or limestone. Moreover, the dust of free silica (probably the most harmful of dusts in mine air) does not always take a form equally harmful; some ores, such as silicious schist for instance, with a free silica content of 60 to 80 per cent., have dust which is much less sharp and probably much less insoluble than other ores such as those of flint or chert which also have 60 to 80 per cent. free silica, the dust of which is, however, very hard and sharp.

Physical examination of miners shows that men who work in very dusty places in coal mines have very definite respiratory disease, whether the dust is from coal only or from a mixture of coal with rock or shale or clay. Men have worked in coal mines and have then gone to work in dusty metal mines and become affected by miners' consumption, or have worked in metal mines and later on succumbed to respiratory disease after having worked in dusty places in coal mines. While dusts insoluble in the fluids and tissues of the respiratory organs are chiefly responsible for respiratory disease in miners, there are certain soluble dusts of lead, arsenic, and other ores which are definitely poisonous or which result in definite harm to the health of workers.

Sources of Dust in Metal and Coal Mines

In Metal Mines.—The main sources of air dustiness in metal mines in the order of their importance are: dry drilling of holes for blasting purposes—the dry drilling of holes pointed upward, especially those from about 70° to vertical, is in general the worst; blasting; shoveling, or "mucking," of very fine dry material at the working face, which is usually poorly ventilated; loading cars from chutes; dumping loaded cars into chutes; and timbering. Dry crushing and other occupations in metal mine mills also have dangerously dusty conditions. One such mill in Nevada, long since abandoned, caused so many fatalities that the death certificates of the victims showed the cause of death as dust from this mill, giving it the name of the mill.

In Coal Mines.—In coal mines by far the most dangerously dusty occupation is the cutting of dry coal by mining machines. Electrical cutting machines usually produce more dust than do compressed air machines. The undercutting machine sends enormous amounts of very fine dust into the surrounding air; shearing, center-cutting, or overcutting machines cause even more dust than undercutting machines. When the cutting is done largely in dry clay or shale, the resultant dust is more harmful than when working with coal dust alone.

Blasting of coal while the shift is in the mine is decidedly dangerous because of possible explosions and

because of the poisonous fumes left; it has the additional very bad feature of throwing into the air large quantities of very fine dust to be breathed by workers. Shoveling dry coal into cars frequently have enormous amounts of a very finely divided mixture of coal and rock or shale dust on haulage or travel roads, and while there is no danger from dust if the ventilation is

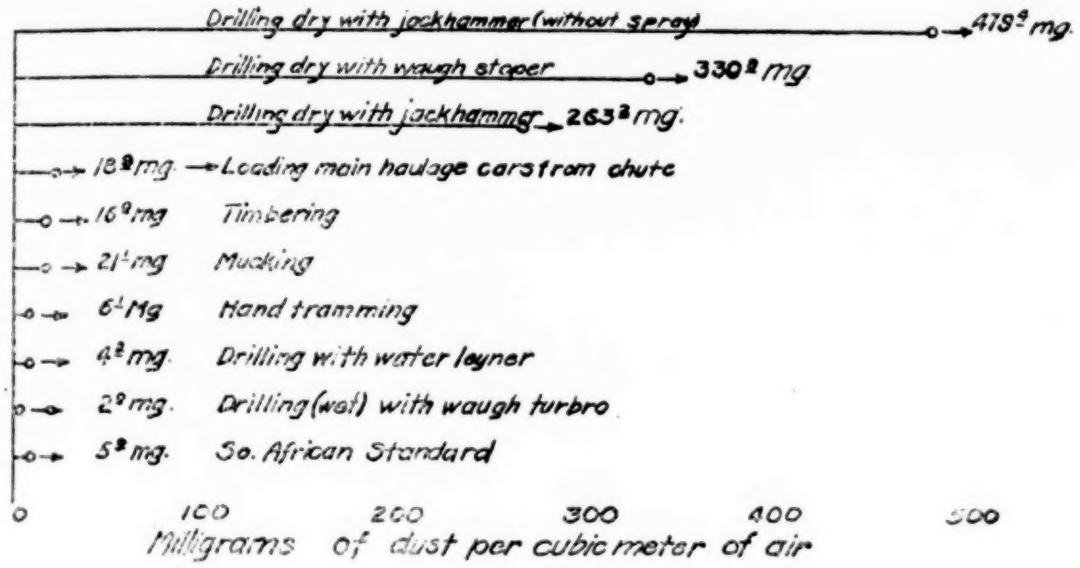

Drilling dry with jackhammer (without spray) 478.2 mg.
Drilling dry with waugh stoper 330.2 mg.
Drilling dry with jackhammer 263.2 mg.
18.2 mg. Loading main haulage cars from chute
16.9 mg. Timbering
21.1 mg. Mucking
6.1 Mg. Hand tramming
4.2 mg. Drilling with water leyner
2.9 mg. Drilling (wet) with waugh turbro
5.2 mg. So. African Standard
0
100
200
300
400
500
Milligrams of dust per cubic meter of air

FIG. 1.—Dust content of air, by occupation, in a well-ventilated metal mine operating in highly silicious ore. Note the high dust content in dry drilling, and the comparatively low dust content with wet drills (water leyners).

and loading dry coal into cars from chutes are also very dusty coal mining occupations, particularly when pillars are being extracted. Some coal miners drill overhead holes into shale or other rock roof to prepare for "brushing" shots to increase the height of low coal workings; when these holes are drilled dry by breast augers or by ratchet augers and the cuttings are allowed to fall through the air past the face of the driller, there is great danger from inhalation of the dust. Similar use of dry jackhammer type of compressed air drills either in the coal or on the rock or shale or clay of the roof or floor, and whether the holes point upward or down, gives such dusty air that the driller and all persons in his immediate neighborhood inhale enormous quantities of very fine, more or less insoluble dust; the condition is decidedly bad if the air circulation is sluggish. Dry coal mine workings good, there is a serious hazard if the air circulation is sluggish or practically nonexistent.

Quantity.—That the quantity of dust breathed is the important point in the harmfulness of dust is the writer's firm belief, yet to state what is that dangerous quantity or what is a safe limit is difficult. In South Africa an arbitrary limit of 5 mg., or 300,000,000 particles per cubic meter of air, was set; their recent reports, however, give the average air dustiness of the working places as but 1.3 mg. per cubic meter of air. There is probably not one dry mine in the United States, coal or metal, where the average air dustiness of working places is as low as 5 mg. per cubic meter of air (the South African standard), or 10 mg. per cubic meter of air (the standard set by Higgins and Lanza in their study of miners' consumption in the Joplin, Mo., district in 1915).

have worked in the dusty air of coal and shale as well as in the dust from ores of hematite (iron oxide), calcite (limestone), and other essentially non-silicious material shows definite

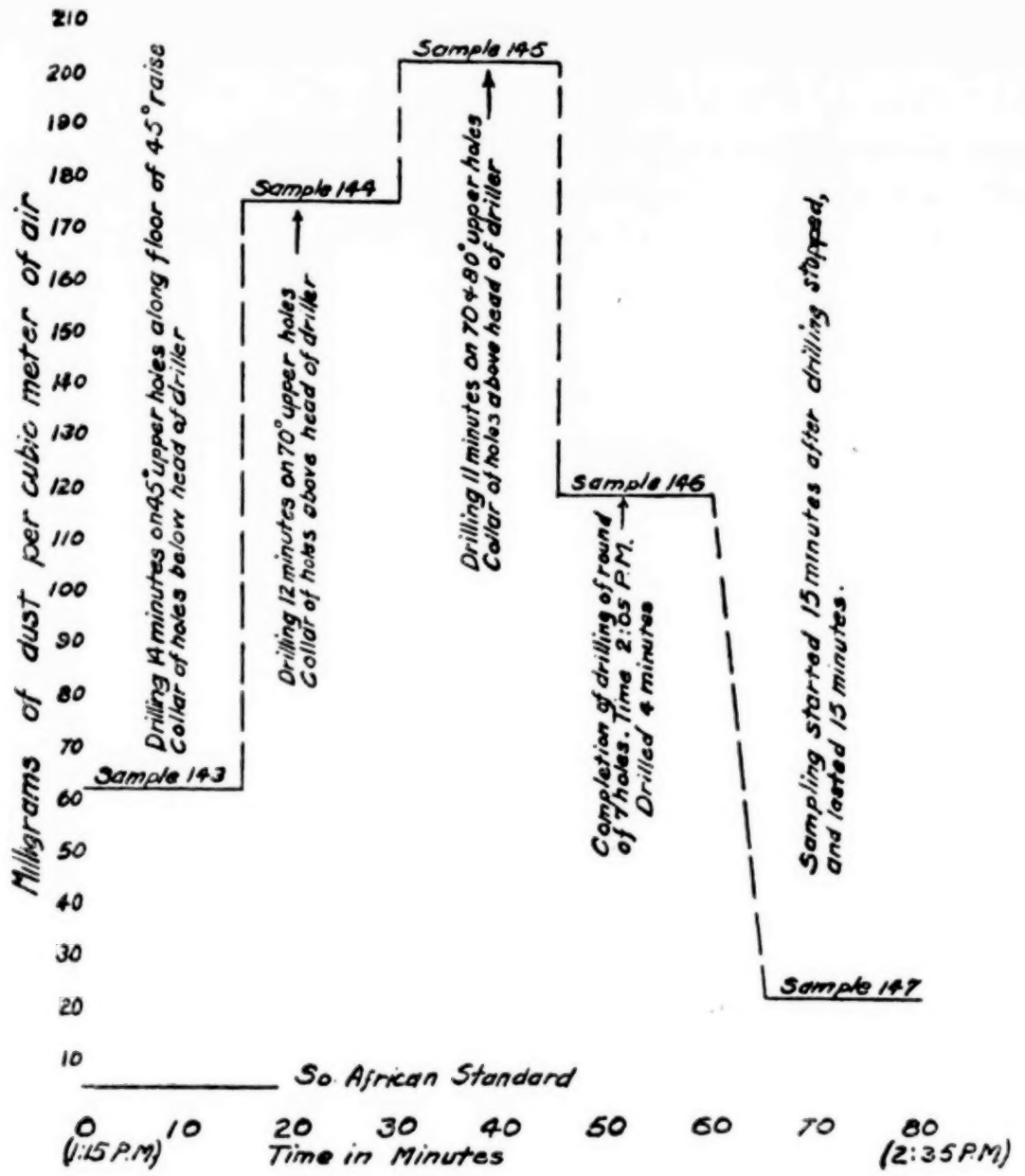


FIG. 3.—Milligrams of dust per cubic meter of air during dry drilling in an average dry raise in our metal mines. Sampling was done continuously during the drilling of an entire round of seven holes.

amounts of lung involvement by X-ray as well as by the usual physical or physiologic symptoms, but especially by shortness of breath.

The fallacy that breathing of coal dust is harmless, or even healthful as some authorities maintain, is readily exploded by the physical examination of coal miners and particularly by X-ray examination of the chest, by the testimony of coal mining machine runners, and by statements of mine officials and coal camp doctors who are observant and will express themselves. Not only does the breathing of large quantities of coal dust give throat or bronchial trouble, as is reluctantly admitted by some authorities, but also the usual symptoms of miners' consumption, including extreme shortness of breath and even hemorrhage, are found only too frequently.

Local conditions intensify the harmfulness of dust in the air. Where men work on a contract basis, they exert a maximum effort, and hence breathe fast and deeply and thereby accumulate maximum dust in the respiratory

organs. Similarly, where the dusty air is high in carbon dioxide or low in oxygen, respiration is accelerated and the lungs take in a maximum amount of dust. When dusty air is stagnant and of high temperature and humidity, say above 80°F. and 90 per cent. relative humidity, the body is depressed, respiration is accelerated, and the dust condition apparently gets its maximum opportunity to harm the worker. Since the very fine dust (from 10 microns down) which can go into the respiratory passages, when once suspended in air by any mining operation, remains in suspension for long periods of time (even with material of fairly high specific gravity), the worker is practically throughout the shift, if the air is stagnant, breathing this dust laden air; hence the importance of having currents of fresh air continually sweeping through and past all working faces and places. Good ventilation (next to the efficient use of water) is the best preventive of dust disease in mines, but the fresh pure air must be circulated where the men work.

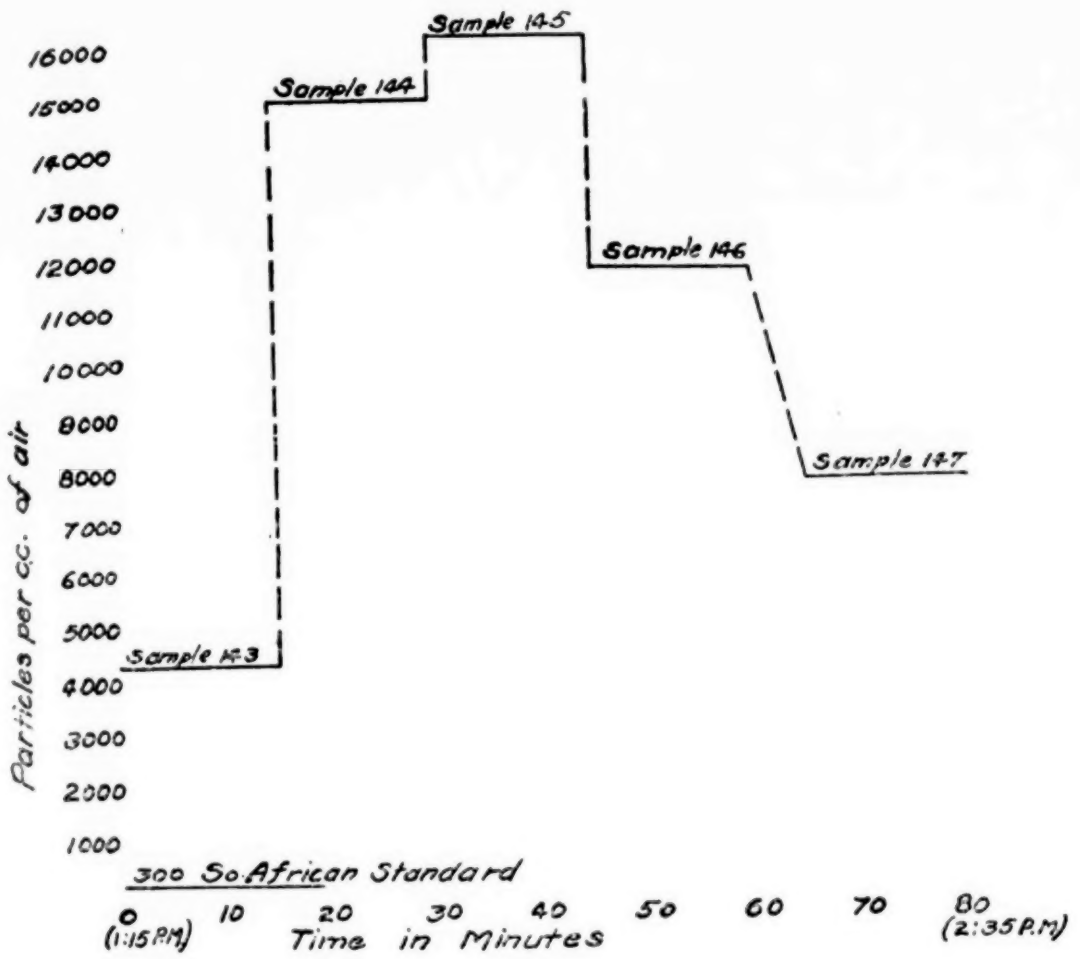


FIG. 4.—Essentially the same data as in Figure 3, given as number of dust particles per cubic centimeter of air.

While the writer is not free to give detailed data as to miners' dust disease at specific places, a few figures and facts will be given to show how widespread is the disease in the United States. In one metal mining locality with silicious ore formation, an insurance company reports mortality as over 500 per cent. of the expected mortality, the excess deaths being due chiefly to lung disease; in another metal mining locality with limestone formation, death expectancy was exceeded by 50 per cent. and again lung disease was held responsible for the

In general, the average air dustiness of working places of our dry metal mines runs above 20 mg. per cubic meter of air and many run above 50. Dry drilling of the upper holes gives run nearly 50 per cent. through 200 mesh and of this a large percentage is probably several hundred mesh.

In coal mines, the weight of dust in the air is not usually so high as in

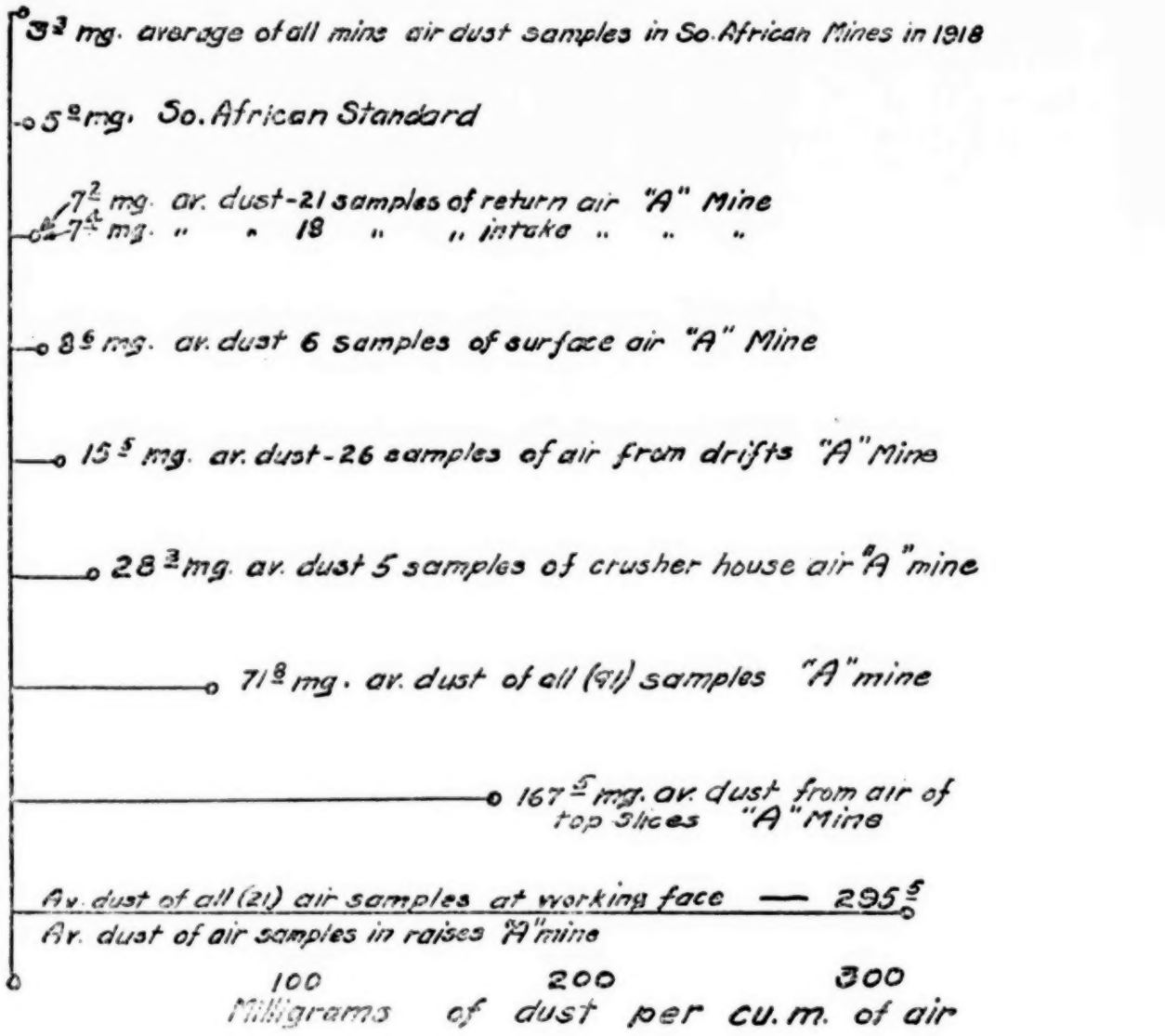

3 2 mg. average of all mine air dust samples in So. African Mines in 1918
5 2 mg. So. African Standard
7 2 mg. av. dust-21 samples of return air "A" Mine
7 4 mg. " " 18 " " intake " " "
8 6 mg. av. dust 6 samples of surface air "A" Mine
15 5 mg. av. dust-26 samples of air from drifts "A" Mine
28 3 mg. av. dust 5 samples of crusher house air "A" mine
71 8 mg. av. dust of all (91) samples "A" mine
167 5 mg. av. dust from air of top slices "A" Mine
Av. dust of all (21) air samples at working face — 295 5
Av. dust of air samples in raises "A" mine
100
200
300
Milligrams of dust per cu. m. of air

FIG. 2.—Comparison of dust content of air in a comparatively well-ventilated but dry, dusty silicious ore mine in the United States with the South African standard and the 1918 record of South African mines.

the air breathed by the driller as high as 7,000 mg. of highly silicious dust per cubic meter of air, or 1,400 times the maximum allowed in South Africa and 700 times the Higgins-Lanza limit. As an average, dry drilling of the upper holes (those above 60°) gives about 150 to 200 mg. per cubic meter of air; with holes under 60° dry drilling gives about 50 mg., while wet drilling gives about 5 to 20 mg. per cubic meter of air. The cuttings from dry drills in metal mines sometimes

metal mines, owing to the much lower specific gravity of coal, but under some conditions the count of particles is almost unbelievable. Shoveling coal in a confined, poorly ventilated very dry place gave approximately eight billion particles per cubic meter of air; numerous places in the same mine where men were shoveling gave from one billion to four or five billions of particles per cubic meter of air. In another coal mine in a place which was not unusually dry, where an

undercutting machine was cutting in coal and without use of water on the cutting chain, the air breathed by the workers had nearly five billion particles per cubic meter of air; of these well over four billion were less than 10 microns in size, hence they were probably breathed directly into the lungs. In these cases much of the eight-hour working shift was spent in breathing air of essentially the above-mentioned type; consequently it is not at all surprising that physical examination showed much miners' consumption among these coal miners.

Effect of Air Dustiness on the Health of Underground Workers

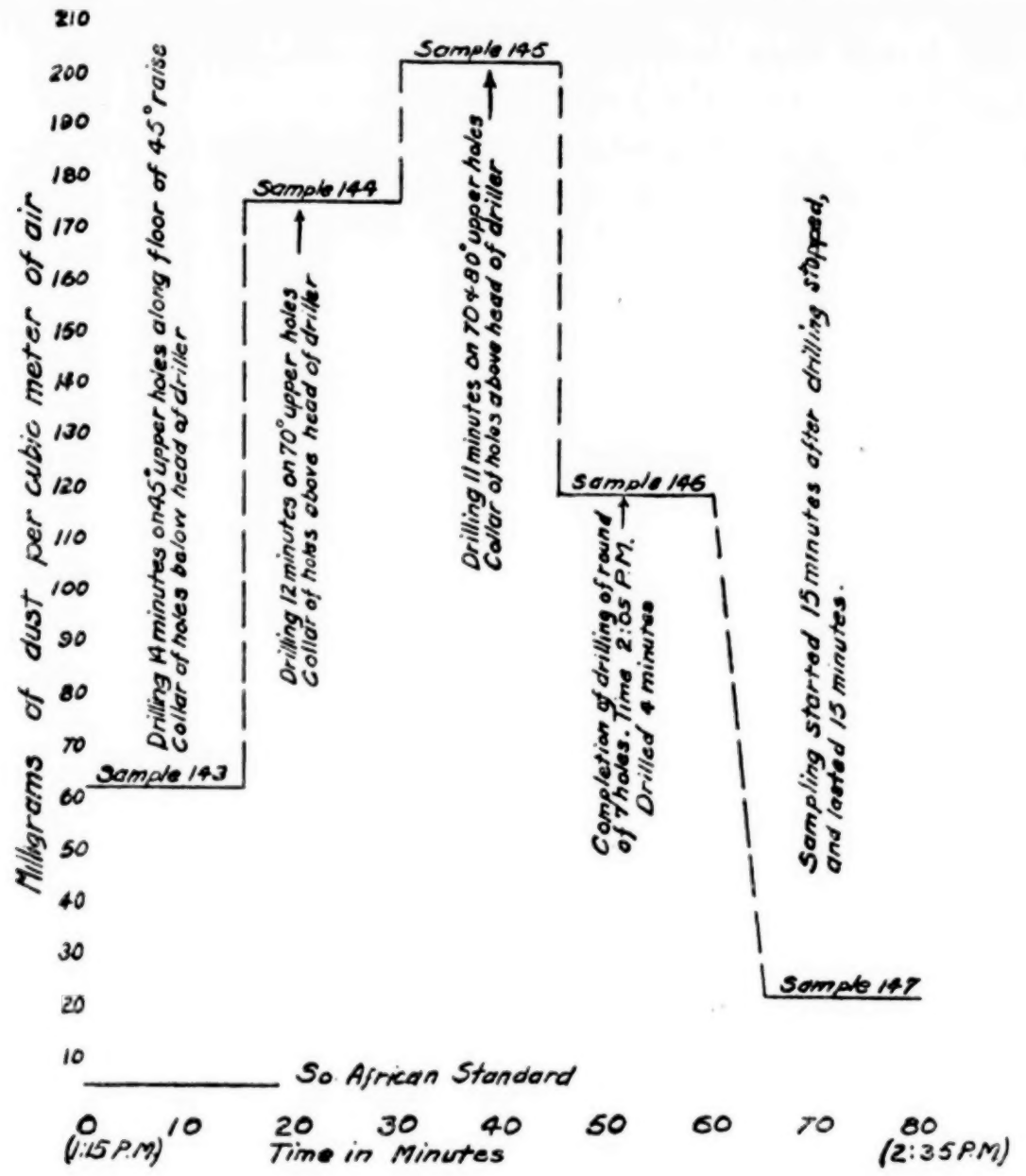
While insoluble dust present in large quantities and in finely divided form in the air breathed by mine workers undoubtedly in itself is likely to be decidedly harmful to health in time, some dusts are more harmful than others, some persons as individuals and some nationalities are more susceptible to harm than others, and some occupations bring out the maximum harmfulness of the dust which is present. There may be contributing factors such as air of high temperature or humidity, or air unduly depleted of oxygen or high in gases such as carbon monoxide, carbon dioxide, etc., which may add to the dust harmfulness by depressing the workers' vitality; or, on the other hand, there may be good ventilation with resultant currents of pure, cool, moving air or water which may be used freely and efficiently to alleviate the harmfulness of dust.

Insoluble dust in mine air generally manifests its harmfulness to the health of miners as some form of lung disease, under such names as miners' consumption, silicosis, anthracosis, miners' asthma, phthisis, and pneumonia; in addition, dusts undoubtedly are largely responsible for much bronchitis, and some soluble dusts are poisonous.

It is the writer's belief that the dusts most harmful to the lungs are from 0.25 micron (possibly as small as 0.1 micron) up to 10 microns in size and that the harm is due chiefly to the filling, or partial filling, of lung cells, tissues, etc., with dust, hence preventing these tissues from performing their normal functions. There is additional harm from the continual irritation caused by these foreign materials and by the efforts made to dislodge them; possibly, too, there may be harm done by the chemical or other action which takes place when the enormous numbers and amounts of the very fine dusts are dissolved. That these small dust particles are dissolved is inferred from the fact that it has been proved that very small particles of flint and chert—material soluble only with difficulty—are definitely soluble in distilled water. Dust particles which result in bronchitis and kindred diseases are probably larger in size—up to 50 or even 100 microns. These larger particles seem not to get into the lungs or at least not to remain there, but they cause considerable irritation in the respiratory passages, and also clog the protective devices and prevent them from intercepting the finer dusts from going into the lungs.

While the dust of free silica such as quartz, flint, chert, etc., is probably the most harmful of the insoluble dusts, physical examination of miners who

have worked in the dusty air of coal and shale as well as in the dust from ores of hematite (iron oxide), calcite (limestone), and other essentially non-silicious material shows definite



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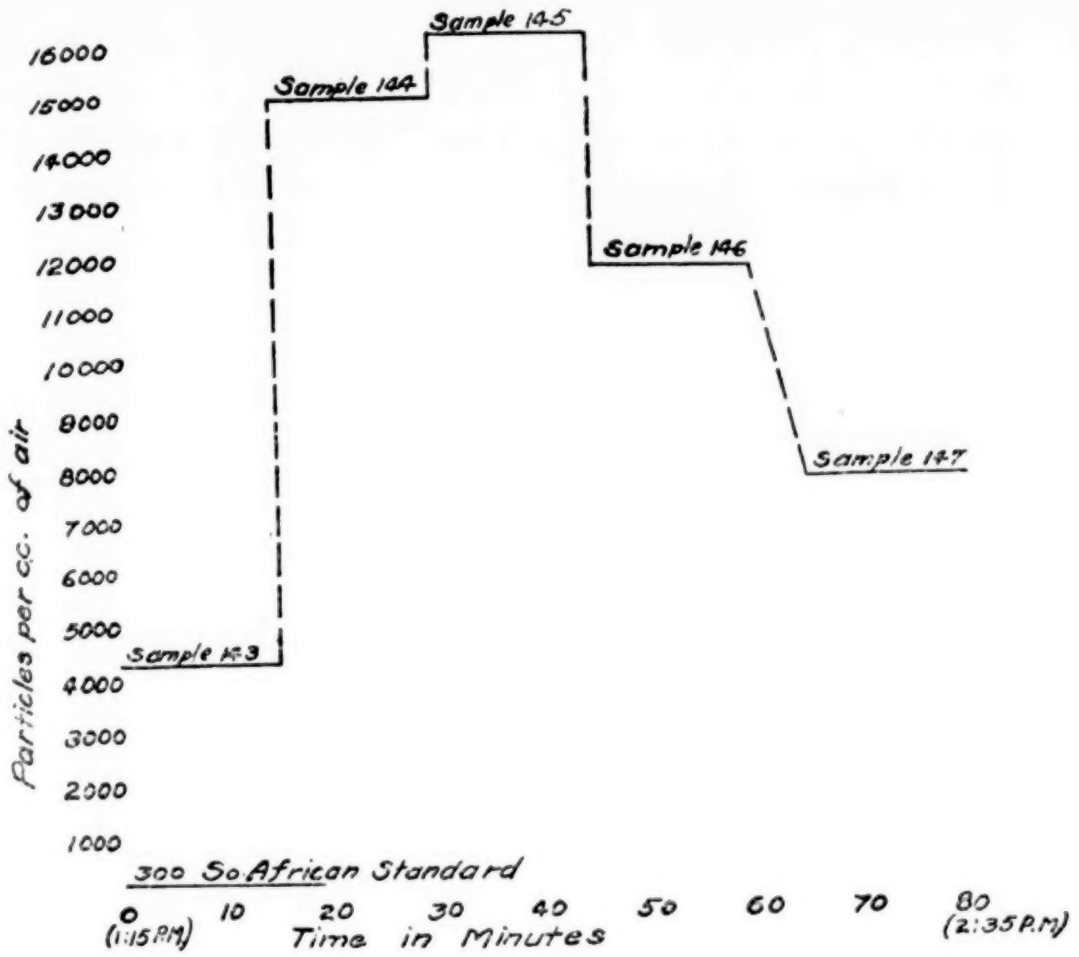

FIG. 4.—Essentially the same data as in Figure 3, given as number of dust particles per cubic centimeter of air.

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excess. In another metal mining district physical examination showed that at least 20 per cent. of all mine workers had silicosis, and of the men who were examined physically and had dust involvement although only a small number were so severely affected as to be incapacitated. In another hematite ore region physical examination of miners was not per-

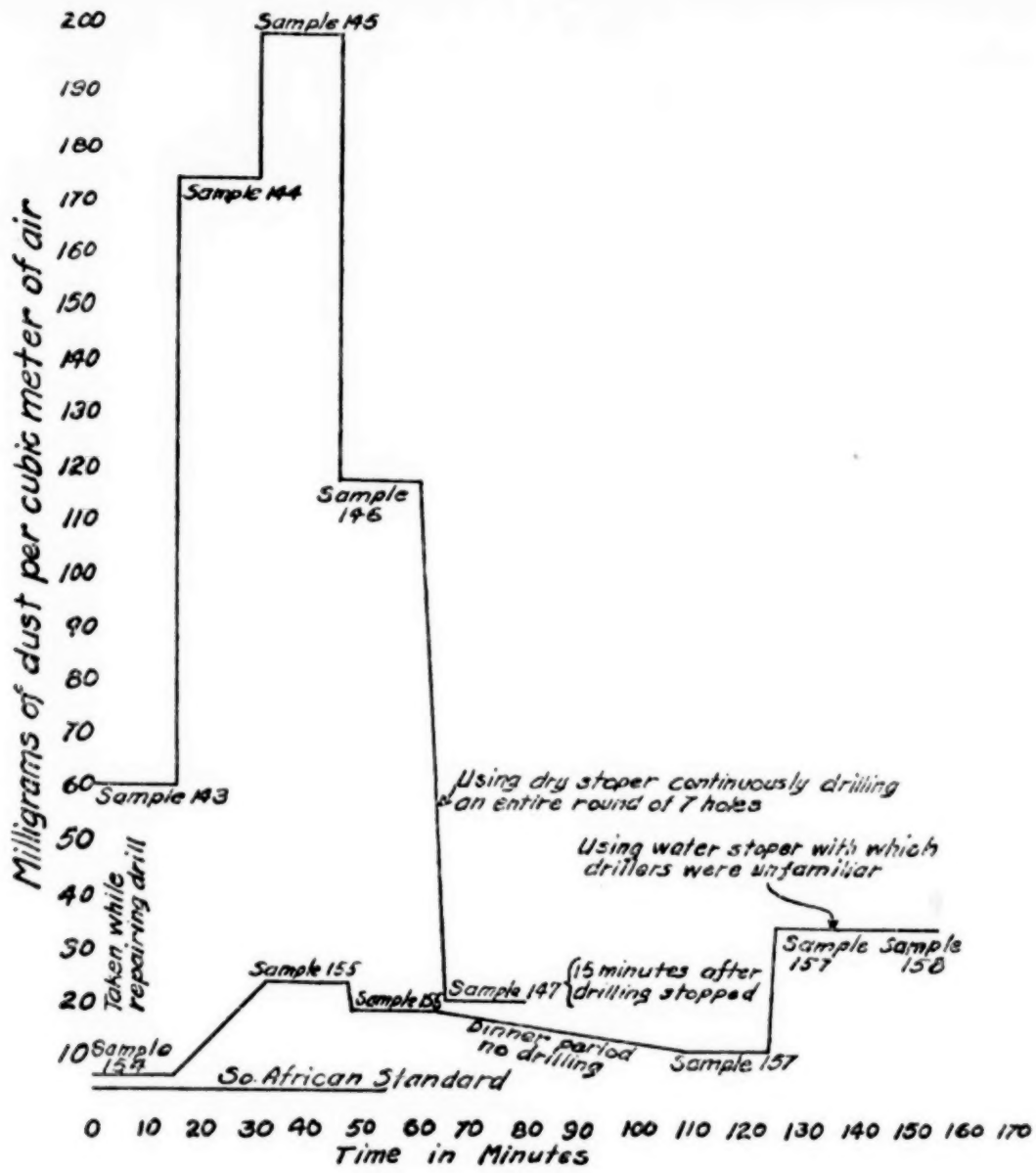

FIG. 5.—Comparison of dust content of air in a dry metal mine during drilling with a dry stoper, with the dust content during drilling with a wet stoper, even when the workmen were unfamiliar with the correct handling of the wet stoper.

	Dry Stoper	*Wet Stoper*
Number of feet drilled	27	26
Actual drilling time, minutes	41	39
Total elapsed time, minutes	50	80[1]
Average dust per cubic meter of air in milligrams	116.1	26.1
Average dust per cubic meter of air in millions of particles	11.180	8.356

[1] Does not include 45 minutes taken for lunch.

had worked only in that district less than 5 per cent. were free from the effect of dust in the respiratory organs. In a metal mine in hematite ore with a very low silica content, about 60 per cent. of those examined physically mitted by the company, but a miner whose health broke down and who threatened suit alleging miners' consumption was given compensation in preference to fighting the suit. In a metal mining district with ore in

calcite (limestone) gangue, considerable miners' consumption was found although the mining company alleged that it was brought in from other camps by those who were afflicted.

Mortality statistics of the coal mining counties of one state over a five-year period showed deaths of coal miners from respiratory disease as 36 per cent. of the total deaths if accidental deaths were excluded; farmers had 25 per cent. and "All Other Males" about 30 per cent. of deaths due to respiratory diseases. In another state, the coal mining mortality record (excluding accidental deaths) showed that 36 per cent. of coal miners died of respiratory disease against 20 per cent. for farmers and 26 per cent. for "All Other Males." In a large coal mining locality about 25 per cent. of the old-time miners were given physical examination; 25 per cent. of those examined had definite lung trouble and nearly 37 per cent. additional had slight lung involvement. In another coal mine with totally different conditions and in a different part of the United States, about 25 per cent. of the underground employees were given physical examination and about 40 per cent. of these showed definite lung involvement. In a number of instances, especially in the western coal mining states, machine runners have been so seriously affected by breathing coal dust that they had to leave the mines and in several cases death ensued within a few years (in one case in less than one year after leaving the mine), the cause being lung and throat trouble; this trouble due to dust in the lungs of machine runners in coal mines has been known since about 1913 in Wyoming and Utah, and the remedy then applied and now largely used is the spraying of water on the cutting chain when the machines are working.

Some individuals seem to have an immunity from dust disease; old-time miners (with underground experience of thirty to forty years in dry dusty mines) have told the writer of numerous friends and co-workers who succumbed to dust disease yet they themselves seemed decidedly healthy. On the other hand, there are records of men who were in their graves from dust disease within a year of the date of first doing underground work; and serious dust involvement due to two or three years' underground work is not at all uncommon. Racially the Finns, the Irish, and the negroes seem most susceptible to health harm from dust; some insurance companies which insure some of the underground workers in dusty mines, but with higher than normal rate, refuse to insure Finns at any rate.

Difficulties in the Making and Publishing of Dust Studies in the United States

While there is absolutely no doubt that dust diseases are directly responsible for the death of several hundred coal and metal miners annually in the United States and indirectly responsible for the death or disability of several thousand others, unfortunately exact figures are unavailable, partly because many doctors apparently do not know how to diagnose the disease, but chiefly for the reason that usually in the regions most afflicted a concerted effort is made toward minimizing the dangerous conditions.

Instead of recognizing the menace due to the diseases and taking ad-

vantage of the available methods of combating or preventing them or at least making a study of the situation with a view to alleviating the harmful conditions and their terrible results, in most instances there appears to be a concerted effort to hide the facts and to take as few measures as possible toward elimination of the diseases and of the conditions causing them. Miners, especially metal miners, whose health is most directly affected usually refuse to allow themselves to be physically examined previous to or during employment; they oppose the use of wet drills which probably more than anything else will remedy the dangerous dust condition and in many instances they destroy or try to make ineffective the water attachments to drills; when water is provided to wet down the dust, the water is generally not used except when the mine boss forces the worker to it; and mine workers only too frequently destroy or partly destroy ventilation equipment installed for their safety, comfort, and health. Mine operators or officials usually deny the existence of miners' consumption or other dust disease among employees, yet frequently some of the mine bosses themselves are afflicted by such disease. Suggestions as to remedial methods or equipment such as sprinkling, or the use of water in drilling or in coal cutting, or the use of currents of fresh air to remove dust are held to be impracticable or are considered the dream of the theorist, even though these methods or devices are in thoroughly successful use in other mines or in other localities. While sometimes the objection to change is due to disinclination or inability to withstand the probable financial outlay, frequently the main obstacle is the fact that mine officials of reactionary type, usually the oldtimer of years of experience and more or less limited education hates to do anything that he has not been accustomed to doing.

In some instances after the higher officials of mining companies have spent large sums of money to install equipment with a view to combating dust diseases in mines, the mine bosses who actually oversee the mine operations are not in sympathy with the "new fangled ideas," and they make little or no effort to cause the workers to use the preventive methods; sometimes the bosses are in sympathy with the new devices or methods but have not the will power or the "back bone" to force the mine worker to use the new method or device. Where labor unions are found around mining camps, the leaders either fail to notice the bad situation as to health of workers or are not mentally capable of reasoning from effect back to cause; in some cases they are undoubtedly subsidized to remain quiet and in most instances they are too busy chasing the almighty dollar for the workers and for themselves to concern themselves with the protection of the health of the workers—this is especially the case since these leaders probably know that generally the workers themselves, as heretofore explained, are not inclined to do their part in protecting their own health or the health of their comrades. Doctors, merchants, engineers, business men in general in the community, even those not directly connected with the mines, who should (and frequently do) realize the gravity

of the situation as to disease among mine workers and their families (as tuberculosis frequently intervenes), from motives of self-interest remain quiet. Death certificates of victims of dust diseases are made out as heart disease, or Bright's disease, or almost anything but miners' consumption or bronchitis, and newspaper reports indicate that death was due to a "lingering illness."

State laws as to dust elimination in mines to prevent disease are usually nonexistent; where such laws are in existence they are extremely meager, and in general they are not enforced as the state inspector feels that it is a hopeless task to try to fight the entire community including the underground workers themselves, whose health is intimately involved and the health of whose families is ultimately involved. Moreover, only a small proportion of the mining public knows or believes that mine dusts are unhealthful and few if any believe that there is possible danger to health from such dusts as coal, shale, limestone ore, and hematite ore; it is the almost universal belief, when dust danger is known at all, that about the only really dangerous dust is silica, and possibly some soluble ores of lead, arsenic, mercury, etc. Instead of actually getting physical examinations or keeping up-to-date records as to the health of miners, old-time statistics, some of which are inaccurate or at least inapplicable to present-day conditions in the mines of this country, are copied and kept in use.

Federal government investigators attempting to ascertain actual health conditions as to dust in the mines of the United States, with a view to aiding in correcting any bad conditions which may be found, are sadly handicapped in trying to obtain first-hand information; and even when definite information is secured, it is a decidedly difficult matter to convey the exact truth even to those directly interested, and it is practically impossible to give the full data to the general public. Federal government investigators have no authority to go underground in mines (except in a few mines on government leased land and these are practically all coal mines), and mine operators frequently refuse to allow access to the mines; generally, although by no means invariably, when consent to go underground is given, it is stipulated that the underground observations be made without allowing the employees to know that the dust problem is being studied, hence the worker's ideas or condition or viewpoint are practically unobtainable. Physical examination of the workers is almost indispensable to a definite knowledge of the effect of dusts and other underground health factors, but only in rare instances were physical examinations allowed; sometimes the company objected, sometimes the miners objected, and in at least one instance state law prohibited the taking of physical examinations. Since federal investigations of health and safety in and around mines are dependent almost wholly on the consent of the operator, it is obvious that if the results of such investigations should be of a nature which reflected unfavorably on the mining company or its operating conditions, the publication of such data would incense the mining companies, and soon not only the specific properties involved but also their neighbors as well as friends

in distant mining regions would prevent the access of federal employees to mines; soon the mines of the country would be closed to federal health and safety inspection with the practical ruination of its usefulness to the mining industry.

As a result of this situation all reports of these federal investigations of dust conditions in mines were necessarily confidential to the federal bureaus involved, and copies were given to the mining operators. In the reports conclusions were drawn and recommendations were made which were usually (though not always) interpreted as criticisms by the mining officials, and were usually bitterly resented; the investigators were attacked as radicals, or theorists, and in some cases were violently abused; and in few, if any, instances were the employees given any knowledge of the data obtained. Even where the reports were the most violently attacked by the mining companies, many of the recommended practices were ultimately adopted; the hostile attitude assumed, however, prevented both the giving of the data to employees who might be directly benefited and the giving to the public of anything like a full or complete report of the conditions. Some mining companies allowed free access to their properties, including the privilege of making physical examinations of their employees, and also consented to full publication of the data obtained. It was held to be inadvisable, however, to take advantage of these offers inasmuch as the publication of full data on any specific locality or localities might cause a demand for like publications concerning other localities where publication was forbidden by the mining companies.

The reactionary attitude of mining companies toward federal investigators and investigations is due in large part to the arbitrary and ill-advised actions of so-called mediators and investigators of the federal Department of Labor during and immediately after the war. While the writer sympathizes with the mining companies with regard to the perniciousness of the above-mentioned mediators and investigators, still the reactionary attitude of the operators toward mine dust and other health and safety investigations in mines prevents the industry (including owners, operators, and employees) from receiving the maximum benefit from studies made by public funds, so that not only the mining public but also the general public (whose interests should not be ignored) are deprived of interesting and useful data, which thus becomes hopelessly buried in files.

Remedial and Preventive Measures as to Dust in the Mines of South Africa Contrasted with Similar Measures in the United States

In the South African mines on the Rand about the same number of miners are employed as in all the metal mines of the United States. About twenty-five years ago a very complete health study was started resulting in the adoption of drastic laws and regulations, which apparently are rigidly enforced and which have resulted in a marked decrease in the incidence of the disease and of the death rate from it. Mines with 1,000 or more men underground must have

men especially detailed on dust and ventilation work; whereas only a few of the metal mines in the United States even consider dust or ventilation. South African mines must have running water in not less than 1-inch pipe within 50 feet of the working place, and with a minimum pressure of 30 pounds a square inch; extremely few of our metal mines, on the other hand, have water available near working faces. South African mines must have water blasts and sprays at or near all working faces; few, if any, of our metal mines have them. All drilling in South Africa must be done with drills in which water flows through the drill into the hole and prevents the formation of dust; most of our miners and mine officials insist that "it can't be done," especially in the drilling of upper holes. In South Africa all blasting must be done after the men are out and the region where blasting is done must be thoroughly wet down both before and after blasting, and men may not enter until thirty minutes have elapsed after blasting; in the United States, however, blasting may be done at any time—in general, no provision is made to wet places at any time before or after blasting and men return to blasted places whenever they see fit to do so. South African mine traveling ways and ore or rock piles must be sprinkled sufficiently to prevent the presence of dust; very few metal mines in the United States do anything toward sprinkling, and most of the mine operators say it is impracticable. In South African mines old workings must be closed, air currents must be split, air dustiness and chemical composition must be determined periodically by sampling and analysis, shift bosses must make daily record of the use of water against dust, and numerous other preventive regulations practically unknown in the United States are in effect and are said to be strictly enforced. Carbon dioxide must not exceed 0.2 per cent. in working places; whereas in the United States many of our workers in metal mines breathe air with a high percentage of carbon dioxide. Carbon monoxide must be less than 0.01 per cent.; but many of our miners have 0.05 to 0.1 per cent. of carbon monoxide at working places during all or a large part of the working shift.

The foregoing regulations and many others are, moreover, strictly enforced in South Africa, where over 80 per cent. of the workers are native Kaffirs and the white men present rarely do the hard, dangerous work at the face, acting chiefly as overseers; on the other hand, in the mines of the United States, where practically all the work is done by white men and where natural conditions frequently are even more unfavorable than are those of South Africa, we have very few and very incomplete regulations, and most of these are ignored.

Conclusions

The outstanding remedy for the bad situation (in many localities a most distressing one) in mines is education—education of mine workers in the necessity of taking such precautions as are available; of mine officials in recognizing the seriousness of the situation and in providing devices and methods to reduce or prevent the incidence of disease and, if necessary, in forcing their adoption on the miners;

of the doctors in correctly diagnosing disease, giving publicity to its prevalence, seriousness, preventive remedies, etc., and in death certificates religiously assigning miners' consumption or other dust disease as the cause where such is the case; and of the merchants, newspapers, and other influences in the community in trying to prevent the disease rather than in hiding its existence.

As specific remedial measures for metal mines the writer suggests the following: Mechanical ventilation with definite person or persons in charge should be adopted to force moving currents of air to every place where men work in order to remove dust, heat, and gases. The use of water should be enforced in all drilling, in the sprinkling of ore and rock piles, in the wetting of timbers, man and haulage ways, and in every place where dust may be found. Where possible, the blasting should all be done after a shift; where this cannot be done there should be enforcement of strict regulations as to the wetting of the region of blasting both before and after firing the shots, as to the removal of all explosive fumes by adequate air currents, and as to the prevention of entrance into a blasted place until all dust, fumes, etc., have been removed. There should also be strict physical examination of mine workers before employment and at periods of not more than six months during employment, with prompt removal from dangerous underground work should unfavorable physical symptoms be found.

In our coal mines, education is also badly needed. The coal mining public, instead of "standing pat" and referring to out-of-date and misleading English statistics that coal dust is harmless to health or is even healthful, should make an impartial but strict study of dust conditions in coal mines (anthracite, bituminous, and lignite), paying particular attention to X-ray examination of the chest; coal camp doctors who have direct knowledge of the harmfulness of coal dust to underground workers, especially those working on mining machines, should come forward with technical articles descriptive of the situation; and state and federal authorities should cooperate in making studies and publishing results as to the health situation of workers in dusty places in coal mines. The introduction of rock dust into coal mines to prevent or to limit explosions is a long step in the right direction toward coal mine safety and, if done with judgment, need not introduce any additional health hazard into coal mines; but if the rock dusting enthusiasts have their way in the placing of rock dust at the already (coal) dusty face regions, there is no doubt that dust disease in coal mines (now present to considerable extent, although usually its presence is denied) will be even more serious than the explosion hazard which the rock dusting is intended to eliminate. If the face regions of our dry coal mines are kept well watered and the rock dusting is done on haulage roads, especially those which are well ventilated, or if the rock dust is placed in nonworking open places, there will be little or no health hazard or explosion hazard. In the use of water at the face region, water should be piped to all dry faces in coal mines and used on the cutting chain while undercutting, overcutting,

center-cutting, or shearing, and the face worker should sprinkle the face region within 50 to 75 feet of the face (ribs, roof, floor, and coal pile) at least three times daily, as well as sprinkle (not soak) the top of all loaded cars before they leave the face.

The writer left the service of the United States Bureau of Mines in July, 1924, after about nine and one-half years' employment in the service and at present is not in close touch with the Bureau or its policies. After having had about fifteen years of commercial mining work (both engineering and operating) before entering the service of the Bureau of Mines and now being again in commercial work, it is his opinion that if the mining industry is to secure the fullest measure of service from the Bureau of Mines, an effort should be made to get authority for its investigators to enter mines and to publish the results of investigations; the Bureau ought not to be given "police" authority, however, to enforce recommendations, but should leave it to public opinion and the fairness of the mining men of the country to adopt such recommendations as are necessary and feasible. It is pure nonsense to say that states can do investigative work on the prevention of explosions in mines, or on health and general safety in mines as well as that work can be done by the federal Bureau; the states have not the broad field that the federal Bureau has and state inspection and state investigations, or private inspection and inspectors, are far more likely to be controlled by politics or by local selfish interests than are federal employees who are on civil service.

The present situation where the federal Bureau of Mines investigators are afraid to publish what they find for fear of ostracism from mines by mine owners, miners' unions, or others who may resent the findings of the investigators and in revenge get the support of congressmen to withhold Bureau appropriations or scale down Bureau activities, results in suppression of many valuable fundamental data and is certainly a condition which gives the mining public but a small amount of the results for which their money is paid out. If the facts as to mine safety and health conditions in the United States are to be made known to those who would be benefited by them, the Bureau of Mines investigators will have to be given authority to enter the mines and publish reports even if they are not given authority to enforce recommendations; if it is left to individual states to get definite, fundamental data as to mine health and safety conditions, such data will never be forthcoming.

This paper is written without the knowledge, aid, or consent of the United States Bureau of Mines or of any member of it and many of the statements are, undoubtedly, at variance with the views of the officials of the Bureau of Mines. The recommendations made, as well as many of the conclusions which have been expressed, will be vigorously opposed by miners, mine operators, and mine health and safety experts, but they represent the writer's ideas formulated after many years' observation and experience, much of the time being spent on a specific study of the subjects treated. Ultimately the general public, whose rights, after all, are directly involved, will demand the

facts and when the facts are known, miners, mine operators, and theorists with pet ideas will have to yield to common sense practices. Moreover, mine operators, who are wide-awake must realize that ultimately (probably within the coming decade) health and sickness compensation will sweep the country somewhat as accident compensation laws did during the past ten or fifteen years; and the wise mine operator will be forehanded and adopt all available methods to "place his house in order."

That the practices recommended in this paper are not entirely impracticable or visionary may be inferred from the fact that several western mining companies are now using the recommended practices. At Butte, Mont., the Anaconda Copper Mining Company, Elm Orlu Mining Company, and other companies have, during the past seven or eight years, spent several millions of dollars in equipping their mines with water pipe lines, wet drills, and good ventilating equipment. Today dry drilling even of upper holes is the exception rather than the rule in Butte, miners use water to wet the chutes, muck piles, and working places, and powerful fans assisted by hundreds of small blowers give circulating air at the working faces. The coal department of the Phelps Dodge Corporation at Dawson, N. M., the Utah Fuel Company, the United States Fuel Company, and other coal companies in Utah use water freely at all dry working faces and also hold ample quantities of circulating air at the working faces while using up-to-date rock dusting methods in the main haulage and non-working territory. These enterprising, very large coal and metal mining companies have adopted the foregoing methods only because they know the methods are safe, healthful, and practicable.

J. I. H.
May, 1925

THE UNHEALTHY BARGEE*

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ANY review of the relationship between occupation and health must always give due consideration to the influence exercised by the home environment of the workers; and, when any particular industry is under consideration, the probable effect of housing conditions on excessive mortality and morbidity rates must be carefully eliminated before coming to a conclusion as to the extent of occupational responsibility. Although there can be no doubt respecting the interrelationship of the two factors, generally speaking, a clear dividing line can be recognized between the two. This brief article has for its object the direction of attention to a class of employment which does not subscribe to the common run of conditions, inasmuch as the occupation and housing of those engaged thereat are inseparable, and it is really to this close interlocking that responsibility for certain well-marked effects on health must be ascribed.

The occupation is that of bargee, or lighterman—a class of worker who, with remarkably few exceptions, is compelled to live as well as work on his barge, flat, or lighter. This is an open-air occupation with no lack of muscular exercise, and although at times it subjects the bargee to severe weather exposure, such occasions are irregular and rarely prolonged to any excessive extent. Another favorable point is that it is most unusual, except on inland waterways, to move the boats except during daylight. So far as the work itself is concerned, therefore, one would undoubtedly expect it to be particularly healthful, and I have personally no doubt of this being the case. As an occupation, however, that of bargeman is not at all healthful; and the reason for this apparent contradiction must be assigned to the disgracefully insanitary quarters provided for the bargee's moments of rest and leisure.

Mortality Records

The decennial supplements to the annual reports of the Registrar-General for England and Wales provide exceedingly valuable information on occupational mortalities, and I propose to quote from the most recent one issued, in order to show what is wrong with the bargee. The period covered is the three years 1910, 1911, and 1912, and a perusal of Table 1 which applies to this particular occupation shows the comparative mortality figure of the industry to be 1,102, which compares very badly with 790, the figure for all occupied males, with 470, the figure for the open-air occupation of farm laborer, and with 858 for what one might conceive to be the like occupa-

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tion of fisherman. Although there is an excessive liability to fatal accidents, as shown by a mortality rate of 193 against the average one of 48, this is by no means sufficient to explain away the high general mortality figure. Life for the bargeman is affected by the drink habit and by venereal disease to a slightly greater extent than is the case with the average male worker; but what really appears to carry him off is his particular liability to respiratory diseases, especially pneumonia. The record of the fisherman, which shows the effect of a life equally as strenuous as that of the bargee, is totally different when respiratory diseases are taken into account. The liability of the bargee to die from phthisis is no higher than that for all male workers (due possibly to lack of exposure to infection), but there is an excessive liability to die from diseases of the circulatory system. The comparative mortality figures given in Table 1 will show the position at a glance.

An investigation into the living accommodation provided on this particular class of craft does not leave much doubt as to the real reason for the excessive mortality from respiratory diseases; nor, to a considerable extent, as to the reason for the greater liability to death from diseases of the circulation.

Results of Inspection at Port of Manchester

The main part of the Port of Manchester consists of a waterway, 36 miles in length, with docks and quays at various points, although the upper reaches of the Mersey are also within the area. A considerable amount of barge traffic is carried between Manchester itself and Liverpool, and between both these points and the other traffic centers along the Port of Manchester. My obligation as Port Medical Officer of Health has been to give attention to the sanitary requirements of these vessels.

During the year 1923 my staff inspected 248 flats and barges, 102 of which were found to be insanitary. On these 102 insanitary boats, the actual insanitary conditions found amounted to 194. It is extremely interesting to note the character of the defects, which were as follows:

Bilges requiring cleaning or inaccessible for this purpose	1
Bulkheads defective and allowing communication between hold and living quarters	11
Decklights broken and defective	15
Defective drainage of quarters	1
Quarters requiring cleansing, painting, etc.	25
Quarters deficient in lighting	15
Floorings, fittings, etc., defective	18
Iron deck over bunks unsheathed	1
Miscellaneous leakages into quarters	58
Ventilation inefficient or ventilators defective	10
No bed berths provided	1
Stoves and stovepipes defective	10
No stove or stovepipe provided	1
Lockers requiring cleansing, painting, repairing, etc.	1
Food stored in cabin without covering	1
Water tanks not accessible for cleansing	1
Water tanks, casks, etc., in defective condition	14
No water receptacle, or receptacle of insufficient capacity	3
Water receptacle kept in a position liable to contamination	6

Barge Accommodation

The housing accommodation on flats and barges usually consists of a

cabin at each end, both being situated below the deck level and not pooped as in narrow canal boats. This arrangement of the quarters enders efficient lighting and ventilation some-

TABLE 1.—COMPARATIVE MORTALITY FIGURES FOR THE THREE YEARS 1910, 1911, AND 1912

	BARGEMEN	FISHERMEN	OCCUPIED AND RETIRED MALES	FARM LABORERS
Cancer	88	88	78	54
Locomotor ataxia and general paralysis of the insane	38	32	18	6
Cerebral hemorrhage; apoplexy	48	31	36	16
Other diseases of the nervous system	36	38	28	21
Diseases of the circulatory system	162	144	118	74
Phthisis	142	101	142	71
Bronchitis	67	21	38	14
Pneumonia	105	55	67	39
Other respiratory diseases	21	12	15	10
Total respiratory diseases (excluding phthisis)	*193*	*88*	*120*	*63*
All other diseases	395	336	250	165
Total mortality figure	1,102	858	790	470

what difficult, and possibly this factor has proved too much for the designers of this type of craft, for it is extremely rare to find even a new boat efficiently provided for in this respect. Barges are manned by a captain and mate and have no other crew so far as my acquaintanceship goes. Their practice is to use the after cabin for living quarters and to use the forward cabin simply for the storage of ship's gear. The sleeping bunks run fore and aft and are placed one on each side of the cabin. The common practice is to separate these bunks from the cabin space by a wooden partition containing a sliding door, instead of by utilizing the more sanitary curtain. A deck light over the bunk space is not usually provided unless at the request of the sanitary authority, and the only means of ventilating the space is *via* the cabin. The lighting and the ventilation of the cabin itself are obtained through a hole in the deck, fitted with an oblong iron frame which has a flange projecting above the deck surface—all this being about the size of a brick. A wooden cover with a glass top is provided to fit over this flange; in good weather it is taken off, but in bad weather it must be replaced to keep out the wet. Every cabin contains a stove with the usual stovepipe projecting above the deck. With reasonable air inlets this functions successfully as the main outlet for ventilation, but when under certain circumstances there are no inlets acting, the stove provides a considerable risk of carbon monoxide poisoning.

One of the worst features connected with this type of accommodation has to do with the method of ingress and egress by means of the old-fashioned scuttle hatch. This consists simply of a square hole cut in the deck which is surrounded by very shallow weatherboards and is provided with a simple hinged or sliding cover. (See Figs. 1 and 2.) It is usually placed on the port side and its position corresponds very accurately with the opening into the mate's bed berth. In wet or rough weather this hatchway, like the ventilator previously mentioned, must be covered if rain or river wash is

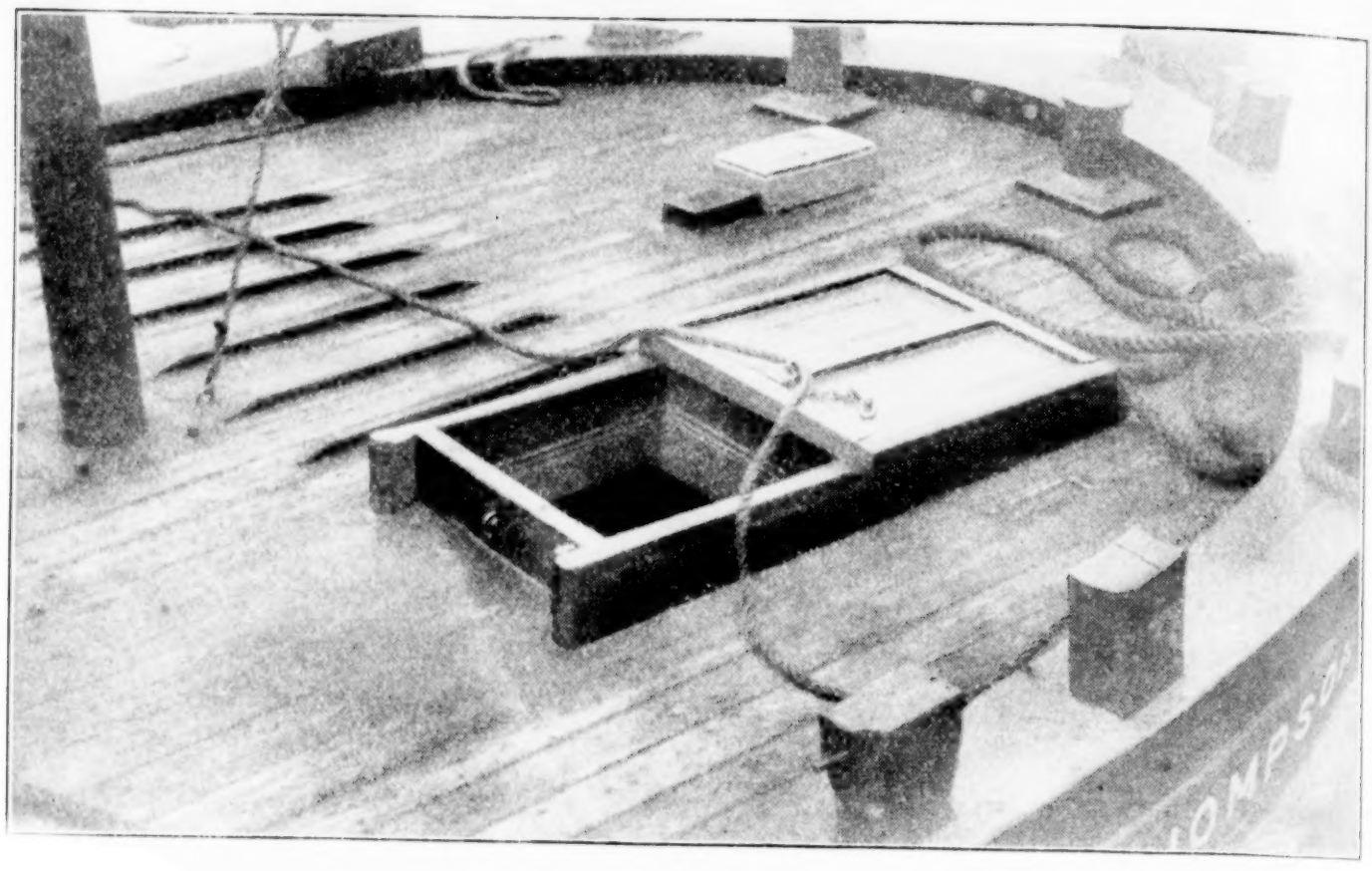

FIG. 1.—Old-fashioned scuttle hatch (open).

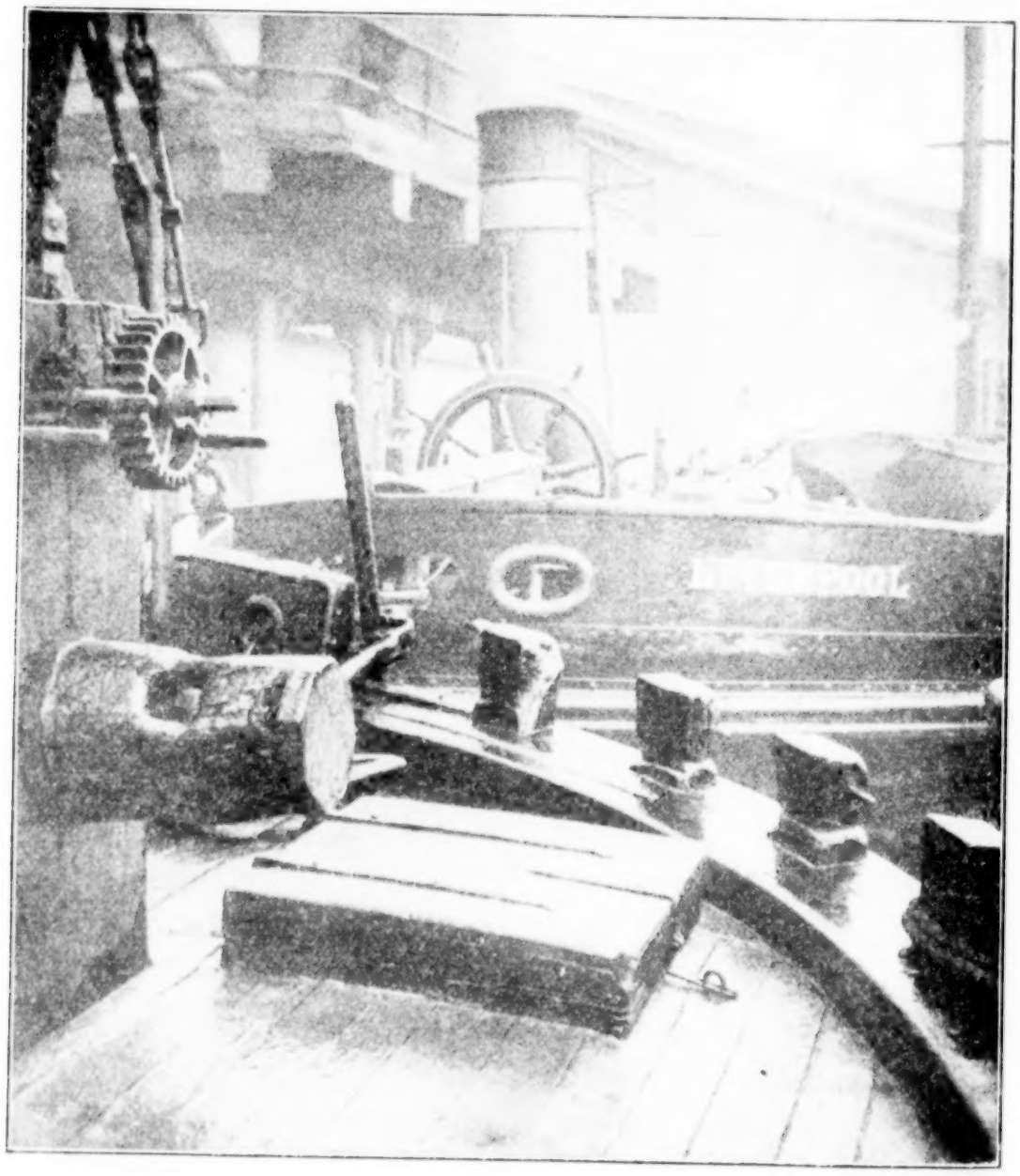

FIG. 2.—Old-fashioned scuttle hatch (closed).

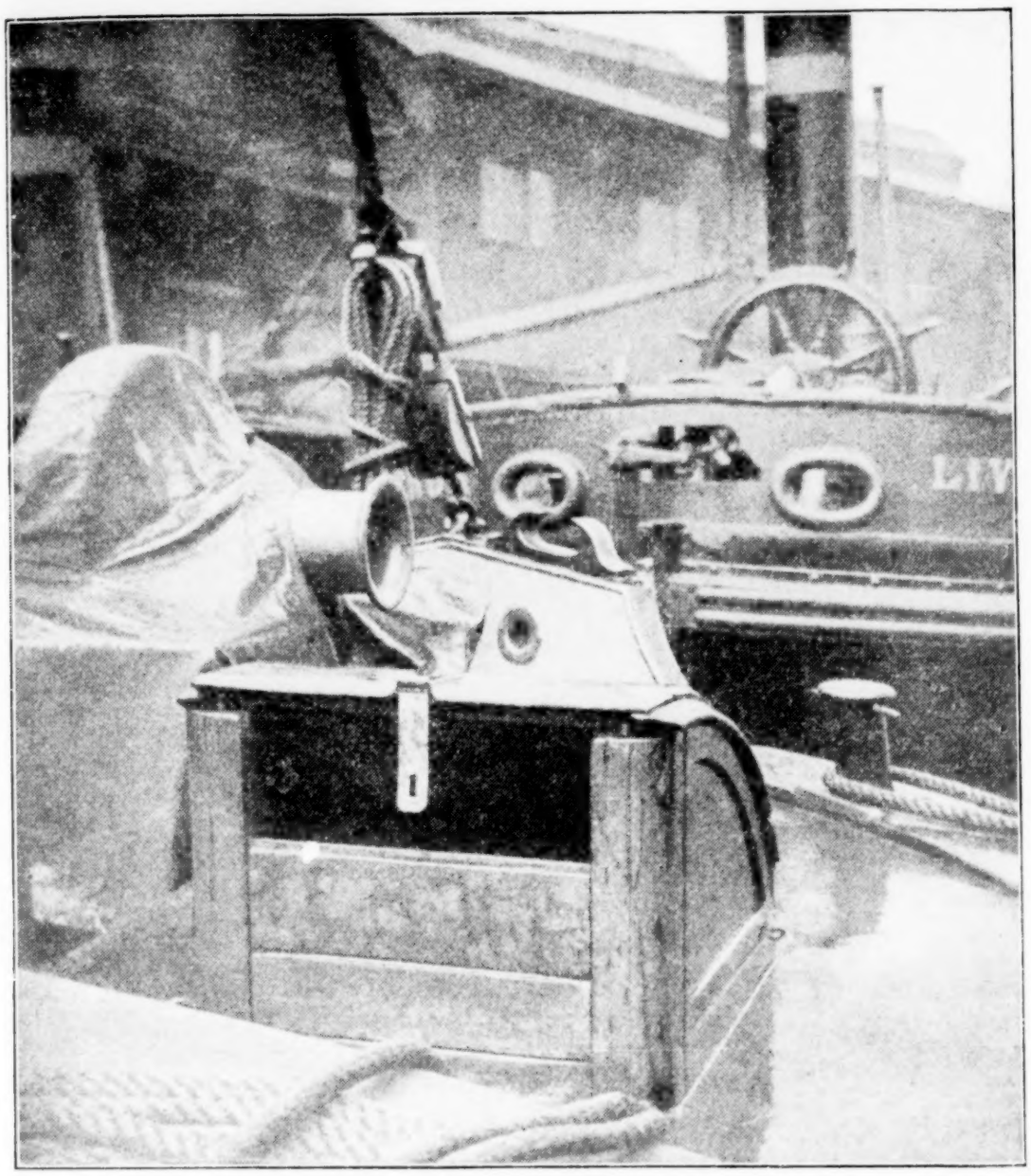

FIG. 3.—Companionway substituted for old-fashioned hatchway.

FIG. 4.—The "Madrid," showing arrangement with sanitary alterations.

to be kept out of the cabin and, incidentally, out of the mate's bed berth. Owing to the fact that these precautions are often not taken during navigation, it is a common experience for the inspector to find the cabin very damp and the mate's bed berth soaked. When the barge is tied up and the berths are being used at night, rain water is liable to enter the cabin and the mate's berth if the hatchway and ventilator are open. If these are closed, there is no ventilation at all. If the mate closes his sliding door as a protection against the rain, he is not much better off, for the same reason.

Improvements

I have been very successful in persuading owners to substitute an effective companionway in place of this ancient hatchway. In shape it is like a quarter drum, one radial aspect corresponding to the opening in the deck, the other being vertical from the deck and providing the main part of the opening, while the top side is the quarter round. (See Fig. 3.) The uprights of the entrance are slotted for the reception of weatherboards and the front part of the round will turn or slide back. In good weather the weatherboards can be out and the top turned back; in bad weather all except the top weatherboard can be placed in position and thus adequate protection is afforded against rain or wash without undue interference with ventilation and light. If in addition each flat side of this companionway is fitted with a hit-and-miss ventilator which can be opened or shut at will, the cabin can be rendered absolutely secure against the weather and still be ventilated. I have also been able to persuade a good many of the owners to provide an efficient type of ventilating skylight in place of the brick-shaped structure mentioned.

Some owners claim that these sanitary alterations interfere with the proper navigation of the vessel, but the contention would seem to be very ill-founded on looking at the illustration of the "Madrid" (see Fig. 4). This shows that there is no obstruction to interfere with the proper manipulation of the tiller, or the handling of ropes. Occasionally a small portion of the cargo space has to be annexed to place the companionway in the most suitable position, and this of course forms a powerful objection to the improvement from an owner's point of view, although many have recognized that the health and well-being of the bargee is of greater importance than the conservation of a few square feet of cargo space.

THE COAL MINER: HIS HEALTH, DISEASES, AND GENERAL WELFARE*

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THE industry of coal mining, after that of agriculture, is today not only the most important of industries, but is also the one employing the largest number of persons. In Great Britain in 1922 it employed 1,148,469 persons. Attention has been directed in recent years from several sides to the miner: to his physiologic needs; to his occupational diseases and accidents; to his psychologic reactions; and to his social environment and mortality. The present paper attempts to condense into one article the main information on these various matters.

The order of presentation chosen is to follow the miner from his home to his work, during his work, and back to his home again, dealing with each subject as it arises.

PHYSIOLOGIC NEEDS OF THE COAL MINER

Food

The miner leaves home carrying with him any food and drink that he will consume while at work. The food, put up the night before, will be cold, as will also be the quart or two of tea he may take to drink.

An interesting series of investigations by Moss (1) gives as high a figure as 4,711 for the average caloric value of food consumed daily by miners. This figure is held to agree well with the results found by Atwater, who calculated that the calories consumed per day by men at work was as follows:

Work	*Calories Consumed per Day*
Moderate	3,500
Hard	4,500
Severe	5,700

Considerable variations about the average figures occurred in Moss's observations (see Table 1). Somewhat contrary to expectation, the greatest amount of food was consumed where the temperature was highest, while the wages standard bore no relation to the needs of the miner for food.

A later and more extensive investigation (2), which does not quite harmonize with the earlier one, suggests that if the caloric value of food consumed as stated above be accepted as correct, an unnecessary amount must have been eaten, since the energy requirements of a miner for a working

*Read before the Bordeaux Congress (1924) of the Royal Institute of Public Health. Received for publication Jan. 6, 1925.

day do not exceed and probably fall a good deal short of 3,500 calories. When allowance is made for the days in the week when a miner does not work, the average net expenditure per day throughout the week is placed at about 3,100 calories, which needs a gross dietary of value approximating 3,400 calories.

These investigations are important since they are basic for any calculations of wages founded on the physiologic needs of the miner and represent an effort at bringing scientific knowledge to bear on a social problem.

The remark may here be made that the mining industry still adheres to the custom, which fifteen years ago prevailed in factory employment, of leaving it to each man to partake of a daily monotonous picnic of unappetizing viands which he has carried with him to work. The industrial canteen has not yet been introduced into the mining industry, even though a pithead kitchen would be simpler to organize than a factory canteen where perhaps 700 workers or more have to be seated at once and served in five or six minutes. Meals from a pithead kitchen could be sent underground in hot, water-jacketed containers placed in empty coal tubs going to various parts of the workings. These tubs would soon reach their destinations, just as tubs containing supplies of beer did in times past, when beer was permitted to be sent into the workings. Miners do not all stop work for food at any definite time, and the service could be extended over an hour or more, thereby avoiding the rush of a factory canteen.

Factory experience has taught that a supply of good food is productive of better work and better health. In this respect the miner, whose physical work is heavier than that of most factory workers, is worse off than are the factory workers.

Drink

Reference to Table 1 shows that miners drink large amounts of fluid daily, and that the amounts vary directly with the temperature of the workings (1). The average hourly loss of moisture for thirteen men in Pendleton mine amounted to 2.4 pounds in weight or about 2 pints—*i.e.*, about 13 pounds in a work period of five and a half hours. During the shift the water drunk amounted to $7\frac{1}{2}$ pounds on the average—not enough to compensate for the loss.

In the United States of America drinking water is supplied underground and instructions are issued by the Bureau of Mines in regard to the best methods of procedure. The safest method is held to be distribution by pipe to convenient points. Kegs, barrels, and tanks, which should be tightly closed, are widely used, however, but they require careful washing and sterilization at least once a week. Drinking fountains, having the jet of water projecting at an angle to the vertical, may be used with either method of supply. A less satisfactory procedure, in force at many mines, is for each man to fill his own pail from a central water supply at the entrance to the mine and carry it with him into the workings.

In Great Britain, on the other hand, all fluid drunk underground is brought from the miner's home—frequently in the form of cold tea—and is carried

below by the man. No water is supplied for miners underground, although it must be supplied for horses in mines. Here again the miner is worse off than the factory workers, since wholesome drinking water must be supplied in every factory unless fewer than twenty-five persons are employed.

TABLE 1.—AVERAGE FOOD, SALT, AND WATER CONSUMPTION OF MINERS EMPLOYED IN MINES OF DIFFERENT TEMPERATURES (MOSS)

DISTRICT	AVERAGE UNDERGROUND TEMPERATURE	AVERAGE VALUE OF FOOD EATEN PER MAN PER DAY	CALORIES PER SQUARE METER BODY SURFACE	WAGES STANDARD ON THE BASIS OF THE HIGHEST	SODIUM CHLORIDE TAKEN DAILY IN FOOD	AVERAGE TOTAL LIQUID DRUNK PER DAY
	°F.	*calories*	*calories*		*gm.*	*pints*
Pendleton	99	5,925	3,386	82	16.9	11.9
Pendlebury	88	5,114	3,044	82	16.8	9.2
Hamstead	79	4,644	2,566	80	16.3	8.5
Forest of Dean	68	4,293	2,494	55	12.6	3.6
Derbyshire	66	4,211	2,491	100	11.3	4.4
Yorkshire	59	4,472	2,555	90	10.9	4.6
South Wales	55	4,320	2,454	88	12.8	3.7
Mean figures for the whole	..	4,711	2,713	..	....	6.5

Athletes know how soon staleness results if hard physical exercise is taken without an adequate allowance of fluid. A miner's working efficiency, especially in hot mines, must be considerably lessened in a situation in which his consumption of fluid is restricted to the amount he can carry with him. In this connection a point of interest to athletes was observed by Moss. A miner, with a reputation for being the best worker in a pit, where the temperature ranged between 77°F. and 82°F., normally perspired freely while at work and lost on an average 1.7 pounds in weight every hour. This man on recommencing work after several weeks' holiday "was unable to maintain his normal rate of sweating, with the result that during the last two hours of the shift he was good for nothing. His temperature had presumably risen. This condition only lasts two days at most" (1). The capacity to sweat freely is not only advantageous to persons taking hard exercise, but appears to be increased by training.

Salt

A further important point emerged from the investigation under discussion (1). Sweat contains chlorides in the form of sodium chloride, 59 per cent., and of potassium chloride, 41 per cent. The content of chlorides in sweat is less when sweating is profuse than when it is scanty, but the total amount excreted is greatly increased by sweating, and a shortage of chlorides in the blood results. If large

quantities of fluid are taken by a person who is sweating to assuage thirst, water poisoning results with its distressing symptoms of muscular cramp. Cramp of this kind occurs among miners in hot mines, among furnace men, and among ship stokers; in severe attacks several men may be required to control the sufferer and straighten out the affected limbs. If, however, the water drunk contains about 10 gm. of sodium chloride to the gallon, cramp is avoided, less fluid is needed to satisfy thirst, and fatigue from exertion more rapidly passes.

Two facts may here be noted. Where barley water is drunk by men at hot processes, the custom has always been to flavor it with salt. The amount of salt consumed daily in food (see Table 1) was found by Moss to be considerably greater for miners employed in hot mines than for men working in cool mines.

Occupational Diseases and Accidents of the Coal Miner

Light and Miners' Nystagmus

Our miner carrying his food and drink with him has now reached the pithead. Here he is provided with a safety lamp, if he is employed in a safety-lamp pit—and, as sinkings become deeper, the proportion of safety-lamp pits is steadily increasing. In 1922, there were in Great Britain 878,997 safety lamps in use by 921,737 persons employed underground in connection with getting coal.

Safety lamps, notwithstanding their proved value in preventing explosions, unfortunately do not give as much light as the old-time naked candles. Photometric observations, a large number of which have been made by Llewellyn (3) (4), disclose the fact that the average illumination at the coal face in safety-lamp pits is 0.018 foot candle—five times less than that in candle pits, or 0.09. Compare this dimness with the standards recommended for adoption in factories (5) of 0.25 foot candle on a horizontal plane at the floor level of an ordinary workroom and of not less than 0.1 foot candle in other parts.

Careful investigation (4) (6) into the prevalence of the disease, miners' nystagmus, has established the fact that it is associated with deficient illumination. This disease does not occur among metalliferous miners, who all use naked lights. Occasionally a case is heard of from candle pits, but the illumination in these pits, although greater than that in safety-lamp pits, is low—lower than that of metalliferous mines, owing to the black, light-absorbing surface of the coal. The great bulk of the cases of nystagmus come from safety-lamp pits. The disease was first recognized soon after safety lamps were introduced and has since steadily increased in prevalence. It is well known among coal miners in France, Belgium, and Germany, as well as in Great Britain, but not in America where, as candles are interdicted, they have been replaced by electric cap lamps which give better illumination. Other factors, such as posture at work and gaseous impurities in mines, have from time to time been put forward as causative, but the evidence is heavily in favor of deficient illumination as the essential factor.

The chief symptom and physical sign of nystagmus is a rotatory oscillation of the eyeballs which occurs in two forms, the latent and the manifest. So long as the condition is latent, the miner has no symptoms, is unaware of the movement of his eyes, and suffers no disability. A large proportion of underground miners in safety-lamp pits—from 18 to 30 per cent.—have been found still at work in this latent condition.

The manifest form may be divided into three types—the slight, in which there is little incapacity, the ordinary, in which underground work has to be given up, and the severe, in which incapacity is complete.

The first and most general subjective symptom is failure of sight, which is most marked at night-time or when the sufferer is called upon to perform the more skilled part of his work. He cannot notch timber and fails to drive his wedge or strike with the pick the exact piece of coal aimed at. He is unable to find his tools after he has placed them on the ground. This loss of sight continues above ground and is most marked at night-time, in the early morning, and at dusk. The man also takes longer to "get his sight," finds the journey to the coal face difficult, and is greatly annoyed by the bobbing up and down of the lights carried by his fellow workmen walking in front of him. He often has to sit down to let "the lights go by," or if of a quarrelsome nature may even strike at a lamp which the man ahead is not shielding properly with a shade or by help of his body. Occasionally the first signs of the disease are bad time-keeping and deterioration of work, leading to friction with the officials.

Sleep is broken both by headaches and dreams; and gradually, but sometimes with startling suddenness, giddiness and temporary loss of sight follow exertion and stooping, and then the lamps and surrounding objects dance and revolve before the workman's eyes. The case is now well developed and the classical signs of headache, often most marked at the back of the head, giddiness on stooping or exertion, loss of sight especially at night-time, dread of lights, and sleeplessness become accentuated. Later on, after prolonged absence from work well-marked neurotic and even hysterical symptoms may appear. In these cases, although almost all objective signs have disappeared, the subjective symptoms remain well marked (4, pp. 16–18).

Oscillation of the eyeballs seldom persists after the miner has been six months absent from underground conditions.

Miners suffering from this disease have a right in Great Britain to compensation. The established claims are not merely more numerous than for any other industrial disease, but actually outnumber claims for all other industrial diseases taken together. In 1922, claims were paid for 8,810 cases (3,924 new cases in the year and 4,886 continued from the previous year). Compensation in this country may, however, be awarded "whether the symptom of oscillation of the eye balls be present or not," and there is no limit to the period over which it may be paid; herein the standard differs from and is far less stringent than that adopted in Continental countries, where, moreover, compensation is not continued beyond six months (6).

The result in Great Britain has been to accentuate the neurotic symptoms which persist after all oscillation has disappeared; thus, in 1920, when 2,865 new claims occurred, there were 2,382 claims which had lasted over twelve months and still remained unterminated, fifty-six having lasted ten years. These figures may be contrasted with Belgian experience which is as follows:

Period off Work	*Percentage*
0 to 1 month	28
1 to 3 months	50
3 to 6 months	20
6 months and over	2
Total	100

Miners' nystagmus, although a distressing condition, is a benign affection. Any fear that the eyesight may be permanently ruined, should be combated. "Most cases of miners' nystagmus are only partially incapacitated; they benefit physically and psychologically by work. Some require work above ground; others are fit for suitable work below ground." Only a few exceptional cases exist to prove the rule that all should return to work within three to six months.

The disease is only to be prevented by adoption of better illumination underground. The problem seems to have been solved in America; and much research has been undertaken to solve it on this side of the Atlantic.

Miners' Beat Knee, Beat Hand, and Beat Elbow

When the miner has reached the coal face, he must assume unusual postures, especially in thin seams. He often has to kneel at his work. When undercutting coal, he lies on his side with one knee tucked up so that the outer tuberosity of the tibia rests against the floor; at the same time the elbow of the same side rests either on his flexed thigh or on the hard floor. Constant friction against the hard floor results in chronic thickening of the subcutaneous tissue overlying prominent bones and in chronic enlargement of the local bursae. Localized areas of lowered resisting power are thus formed. If infection gains access through some minute puncture, through sodden skin when the workings are wet, or through the blood stream when the general health is poor, a condition of inflammation and suppurative cellulitis is particularly liable to develop. Subcutaneous cellulitis originating in this way is known as miners' beat knee or beat elbow, according to the part affected; the former is far more prevalent than the latter.

The handle of the pick, especially if it is not smooth or if rock or hard coal is being worked, acts as a source of chronic trauma to the palm of the hand. In this locality no definite thickening of the subcutaneous tissue can be detected, but, if infection occurs, an acute localized infection results which proceeds to suppuration. This condition is known as beat hand.

A fourth condition, inflammation of the synovial lining of the wrist joint, or noninfective tenosynovitis, may also result from continued use of the pick. This condition is not associated with suppuration.

These four conditions are included in the Schedule of Diseases of the Workmen's Compensation Act, 1906, and entitle the sufferers to compensation. They occur so predominantly among coal miners, especially among those employed underground, that, although other persons also contract these diseases occasionally, their study may be best followed in the mining industry (7). In 1922 the number of new claims established among miners was as follows: beat knee 1,721; beat hand 1,138; beat elbow 200; noninfective tenosynovitis 173; giving a total for all four diseases of 3,232 (as

contrasted with 4,091 new cases of miners' nystagmus).

These diseases present another contrast to miners' nystagmus with regard to the duration of incapacity, thus:

Disease	*1922 Total Cases*	*Cases Continued from Previous Year as Percentage of All Cases*
Miners' nystagmus....	9,146	55.3
Beat knee.....	1,815	5.2
Beat hand.....	1,216	6.4
Beat elbow.....	213	6.1
Noninfective synovitis	179	3.4

These four diseases are clearly not only less prevalent than miners' nystagmus, but they give rise to far less invalidity and incapacity per case. Of all the diseases included in the Schedule to the Compensation Act, nevertheless, beat knee ranks second to nystagmus for number of claims and beat hand third, while beat elbow ranks about equal fourth with lead poisoning.

An understanding of the way in which these diseases originate points to means for their prevention. Cases of beat knee would be greatly diminished in number by the use of knee pads by miners working in thin seams and by scrupulous attention to cleanliness of the skin, for which purpose pithead baths would be of great value. Attention to the smoothness of pick handles and instruction in the proper use of a pick would lessen the cases of beat hand and also of noninfective tenosynovitis. Well-organized first-aid treatment and equipment would reduce the development of each disease by preventing the neglect of apparently trivial injuries.

Parasitic Diseases

A reference should be made here to two diseases which have occurred among coal miners because of the fact that conditions underground are favorable for the transmission of certain forms of infection.

The first is hookworm disease, *ankylostomiasis*. In some parts of the world, especially in Germany and California, as high as 80 per cent. of the miners have been found infected. In Great Britain the disease has been discovered to be prevalent among Cornish tin miners, but coal miners are not known to suffer from it; hence further reference to the disease is not made here.

The second is *spirochaetosis icterohaemorrhagica*. This disease primarily affects rats and is possibly transmitted by them to human beings. Efforts are made in Great Britain to keep mines free from rats, but in at least two wet coal mines in East Lothian which were studied numerous rats existed. Exactly how these rats became infected is not clear; possibly through an infected miner returning from war service in France where an epidemic of this disease occurred. There is evidence that unusual cases of jaundice occurred in the district soon after the war, and they may have been due to this disease. During 1923 a number of cases of jaundice, varying in intensity, occurred among, the miners, with four fatalities. Some of the patients who were admitted to the Royal Infirmary, Edinburgh, were carefully studied by Buchanan (8) who found spirochetes in their urine and also in the rats from the infected area. Later Buchanan (9) found the

leptospira concerned living in a slimy, viscid substance hanging from the roof in an old section of the pit where the infected miners had worked. The pit was not deep and infection may conceivably have occurred through moisture percolating down from the surface. Guinea-pigs injected with infected urine or with the slime developed the disease, after which numerous spirochetes were recovered from the liver. A serum has been prepared from the horse which would appear to be curative in these cases. Prevention lies in the removal of infected slime and in the suppression of vermin, as well as in sanitary cleanliness in the mines.

Diseases Due to Exposure to Mine Dust

The coal miner is clearly exposed to dust; it is generated for the most part from the coal he is getting, but also from the material of the strata in which the coal is found. In both, more particularly in the latter, free silica is to be found.

Dust when inhaled varies in the effects it produces, the variations depending on the chemical nature of the dust and the size of the dust particles. The most injurious dusts are those composed of silica (SiO_2) with particles less than 5 microns in diameter. Such particles are fine enough to gain access to the pulmonary alveoli, whence some are carried by macrophages into the lung tissues; there they appear to be converted into soluble silica, a toxic substance reaction to which results in the formation of fibrous tissue. Lungs so altered are particularly liable to succumb to tuberculous infection, while the infection, in its turn, hastens the course of fibrosis. No other form of dust is known to possess this specific relation to tuberculosis.

Particles of dust, too large to reach the alveoli, adhere to the mucous lining of the air passages whence they are expelled in mucus. Prolonged exposure to such dust leads to overaction of the mucosa and to the development of bronchitis, and the subjects are more than usually prone to pneumonia. All forms of dust, except those easily soluble in the body fluids—*e.g.*, calcium salts—if inhaled in sufficient amounts over long periods, act in this way as mechanical irritants.

Coal presents an instance of a dust which appears to possess the property of inhibiting the toxic action of silica (10). This substance is present in small percentages in many coals and in appreciably dangerous amounts in coal measure shales and other rocks. Certainly coal miners experience, all the world over, a low mortality from phthisis, and present a sharp contrast with metalliferous miners, such as gold, tin, and lead miners (11). Nevertheless, low as their phthisis mortality is, the experience for coal miners displays certain statistical characteristics which are distinctive of dust phthisis or tuberculous silicosis; these are (1) an unusually late age of maximum incidence and (2) an association with high mortalities from other respiratory diseases. The first characteristic is exhibited in Table 2; the second in Table 3, wherein the phthisis mortality on the different coal fields is seen to vary directly with variations in mortality from pneumonia and bronchitis.

More intensive investigation (12) brings out the fact that the miner at

the coal face suffers from phthisis rather more than other miners below ground and workers above ground; and that phthisis among workers above ground has an early and not a late age of maximum incidence.

TABLE 2.—MORTALITY PER THOUSAND FROM PHTHISIS FOR THREE DECENNIAL PERIODS AMONG PERSONS EMPLOYED IN CERTAIN OCCUPATIONS AND AT VARIOUS AGE PERIODS

OCCUPATION	PERIODS	AGE PERIOD						
		15–	20–	25–	35–	45–	55–	65 and over
Coal miners	1890–92	0.58	*1.39*	1.21	1.45	2.07	*2.23*	2.03
	1900–02	0.41	1.03	0.96	1.09	1.52	*2.04*	1.47
	1910–12	0.54	1.81	0.84	1.02	1.31	*1.43*	1.02
Tin and lead miners	1890–92	1.10	3.21	3.78	6.15	10.59	*13.85*	*13.89*
	1900–02	0.56	1.54	6.01	7.85	10.50	*12.22*	10.00
	1910–12	0.20	2.31	3.24	9.23	10.44	*13.72*	8.24
Printers	1890–92	1.42	4.21	4.97	*5.87*	5.22	5.30	4.39
	1900–02	1.03	3.45	3.65	*5.13*	4.34	3.68	1.87
	1910–12	0.78	2.60	2.64	3.07	*3.37*	2.90	2.19
Inn servants	1890–92	0.42	2.73	6.01	*11.15*	8.65	3.95	2.40
	1900–02	0.80	2.20	5.49	*9.99*	9.65	5.48	6.51
	1910–12	0.57	1.26	3.13	*5.02*	4.91	3.85	1.50
Agricultural laborers	1890–92	0.41	1.41	1.83	*2.11*	1.87	1.60	0.95
	1900–02	0.30	1.05	1.15	1.29	*1.43*	1.26	0.75
	1910–12	0.28	0.82	1.00	*1.10*	0.98	0.87	0.61
All males	1890–92	1.11	2.15	2.76	*3.48*	3.47	2.86	1.44
	1900–02	0.82	1.69	2.16	2.89	*3.15*	2.52	1.33
	1910–12	0.74	1.38	1.70	2.09	*2.29*	2.17	1.14

The conclusion seems to be that coal miners are affected by the dust they breathe and owe at least a proportion of their mortality from respiratory diseases to this cause.

Diseases Due to Exposure from Stone Dusting

A mixture of fine organic dust and air is explosive. In mines, coal provides the organic dust. Chance ignition of inflammable gases emanating from coal may start a wave of detonation. Such a wave disturbs coal dust lying on the sides and floors of the galleries, wafts it into the air and so forms a mixture which, in its turn, explodes and passes on the wave. In this way, ignition of a small pocket of inflammable gas in one corner of the workings may initiate an explosion which travels far and near throughout all the roadways of the mine.

If, however, the coal dust on the floor and sides contains about equal parts of fine, inert dust, then the mixture formed with air has been found

not to be explosive and to be incapable of passing on a detonation wave. Discovery of this fact has led to adoption of the practice of dusting the roads of coal mines with inert stone dust. The question has then arisen as to whether the dust so introduced may not introduce a further danger of its own from dust inhalation. Mortality data from other industries indicate that no danger is to be anticipated from the use of limestone dust which, moreover, being light in color, has distinct advantages from the point of view of nystagmus. Dusts containing silica are to be carefully avoided and no material should be used about which any suspicion can arise (13).

Probably no dust, if inhaled in sufficient amount, is entirely harmless. Hence the process of stone dusting needs to be carefully regulated. It should be done when there are as few men as possible in the workings, and those employed should proceed down the air current so that the dust does not blow back but is rather carried away ahead of them.

The value of stone dusting for preventing explosions cannot be doubted; the probability of any ill resulting from dust inhalation is small under good practice, but the certainty of its harmlessness can only become manifest after years of experience.

TABLE 3.—COMPARATIVE MORTALITY AMONG COAL MINERS, AGES 25 TO 64, INCLUSIVE

COAL FIELD	1910–1912					1900–1902				
	All Causes	Phthisis	Pneumonia	Bronchitis	Accidents	All Causes	Phthisis	Pneumonia	Bronchitis	Accidents
Nottinghamshire[1]	570	53	40	25	66	675	64	52	49	80
Derbyshire[1]	591	70	34	39	73					
Northumberland and Durham	635	70	54	33	83	763	84	54	41	105
Staffordshire	717	74	70	61	109	846	66	71	104	118
Yorkshire	758	81	69	45	117	783	88	71	67	99
Monmouthshire and South Wales	777	70	69	66	131	951	93	108	104	169
Lancashire	941	107	100	88	183	1,006	96	149	113	131
All coal fields	727	76	64	51	118	885	89	86	79	123
Occupied and retired males	790	142	66	38	47	1,004	187	92	58	58

[1] Nottinghamshire and Derbyshire were grouped together previous to 1910–1912.

Accidents

Mining, with its own special risks, has an evil reputation for the occurrence of accidents. No attempt is here made to deal with the technicalities of mining engineering through which so much has been done to reduce underground accidents. Attention is mainly

drawn to the importance of the personal factor in accident causation.

Mortality from accidents among miners in 1910 to 1912 was, among occupational groups, only exceeded by that of seamen and bargemen. The mortality experienced amounted to nearly one-sixth of the total mortality as compared with one-seventeenth for all males. The mortality records of coal miners are set forth in Table 3; the mortality from all causes varies considerably on the different fields, as also do the rates for accidents and for each of the respiratory diseases. If the rates for the particular causes of death stated in the table are subtracted from the rates for all causes, the difference in rates among the various coal fields is largely obliterated. The accident rates on the different coal fields are found, in 1910 to 1912, to place the coal fields in the same order as the death rates for all causes; and the same is nearly true with regard to the rates for each of the respiratory diseases.

The deduction obtrudes itself that conditions which lead to ill health, particularly of the kind which terminates in death from respiratory disease, have also some underlying influence on accident causation (12); probably the ill-being which the conditions cause is at the root of the matter. "Carelessness" with regard to safety is largely an expression of ill-being; a man who is healthily alert is not naturally careless. This deduction receives some support from the figures given in Table 4 of the average annual deaths per million persons employed at all mines (14, p. 35):

TABLE 4.—AVERAGE ANNUAL DEATHS PER MILLION PERSONS EMPLOYED AT ALL MINES

CAUSE	1873–1882	1911–1920
Natural causes:		
1. Explosions of firedamp or coal dust	610	107
2. Falls of ground	1,112	748
Mechanical causes:		
1. Shaft accidents	352	81
2. Haulage accidents below ground	296	304
3. Other accidents below ground	193	141

> These figures indicate a very striking decrease in the number of accidents due to explosions and to shaft accidents, for the prevention of which much has been done by research and regulation, and an improvement less marked in the number of accidents due to falls of ground, in the prevention of which, though many are of course unavoidable, personal care plays a predominant part. On the other hand, no improvement is evident in the number of accidents on haulage, an operation in which safety depends far more on the personal factor than on regulation, and in which the work of the individual is not open to close supervision.

If the same reduction that has been effected for explosions and shaft accidents could be obtained for haulage accidents and falls of ground, the mining industry would lose its unenviable reputation. The element of personal

carelessness cannot be entirely eliminated even from explosions and shaft accidents. In factory employment this element has been calculated to account for not less than 80 per cent. of all accidents. It is probably at least as important in mining.

Many of the things here advocated —improved illumination, food kitchens, drinking water, and pithead baths—would, by improving the health, efficiency, and self-respect of the miner, have an indirect, but considerable, influence in reducing the frequency of these "personal factor" accidents. They require, however, to be reenforced by that form of education known as the safety-first movement; already a few colliery managers have initiated this movement with marked success. Nevertheless, up to the present the personal factor in the causation of accidents in mines has received far too little attention.

First Aid.—Little need be said regarding first aid in mines, or its value in reducing severity rates due to major or minor injuries. The principles and the need are the same as those applicable to factories, and the intention of the writer is to refer only to medical matters of special interest to the mining industry, or which have come to light through recent investigations in the industry.

One point may be stressed. It refers both to first aid and to rescue appliances. There is need for medical supervision to insure that the appliances provided are properly used and that records are kept of each accident, however trivial it may be. Only by study based on records kept can investigation be made into the way in which large numbers of minor injuries occur. Reduction in this class of injury means a greater reduction in sickness and lost time than can result from further lessening the occurrence of explosions, which are far more spectacular, but in the long run cause less injury to life and limb.

Rescue Work.—Rescue work, on the other hand, owing to the ever present danger from explosions, is essentially peculiar to coal mining. Much research work has been carried out, particularly by Haldane, into the causation of death resulting from explosions and into means for effecting the rescue of unconscious men. Death occurs in the majority of cases from gassing with carbon monoxide resulting from incomplete combustion of coal dust (which forms with air an explosive mixture). If men so gassed can be removed from the noxious atmosphere as soon as possible, they may be restored to life by artificial respiration. When once this fact was ascertained, the problem resolved itself into devising means for entering the atmosphere safely. The means are now provided at rescue stations on every mine field in the form of oxygen apparatus to be worn by the rescuer, who is thereby rendered independent of the air he enters for his oxygen supply. The rescuer must, however, be physically fit and trained to his work.

As the result of research among miners and others (15) into physical fitness, the claim has been put forward that a person in good training takes up more oxygen from the same amount of air breathed than one not in training; in other words, that he can secrete oxygen inwards through the pulmonary epithelium. Hence, on exertion he can satisfy his oxygen

needs with less respiratory effort. This fact is of more value to the athlete than to the rescuer who cannot obtain for use more oxygen than his apparatus contains; but he should not, by unnecessary exertion, use up the supply rapidly. A man, like an engine, has a most economical speed at which he goes farthest per liter of oxygen or per pound of food. The most economical rate of walking in a mine when wearing an apparatus appears to be about $2\frac{1}{2}$ miles an hour, as compared with about 4 miles an hour unburdened on a smooth level floor, and rather over 3 miles on an ordinary road. The rescue worker who, finding his oxygen supply running short, quickens his pace beyond the economical limit in his desire to reach fresh air, seriously impairs his chances of ever reaching his goal. He must maintain his pace in order to use the available supply as economically as possible.

The provision of rescue apparatus and appliances, and the establishment of central rescue stations and brigades are now enforced throughout the coal fields of Great Britain under General Regulations issued in 1913, and special provisions made in 1914.

Psychologic Reactions in Coal Miners

Rhythm and Method in Work

The custom of industry is to leave each manual worker to discover for himself the best way of using his own body. No organized scheme is adopted, as in the field of sport, to teach how a blow should be struck or strength used; the boxing instructor and the golf professional have no counterparts in industry. Instruction in how to play is taken seriously, but is disregarded in the matter of how to earn a livelihood. Coal mining is no exception. Interest, therefore, attaches to a short investigation made with this end in view (16).

The factor of rhythm in coal getting was particularly studied. The best workers were found to use a comparatively slow stroke of the pick in getting coal and a faster one working on harder rock; the rate of stroke also increased with the hardness of the coal. The quicker rate for hard material arose from utilizing the rebound of the pick; in the softer coal, the point of the pick tended to stick and a slower stroke was needed to allow time for withdrawal without losing the rhythm. A metronome was introduced and set beating to the rhythm of the best miners; other groups of miners, one after another, were induced to follow the rhythm set by the metronome. Once taught, the men were found able to maintain the rhythm on their own initiative. Calmness now characterized work which previously had appeared spasmodic, while output increased from 6 to 16 per cent. These results were obtained with old miners, but if similar training were given to young men just beginning to work who had not already formed contrary motor habits, still better results should be obtained.

Work on these lines has been done in other industries and valuable results have followed, the value being greater in proportion to the extent that the pace is controlled by the operatives rather than by a machine. Coal getting in Great Britain is mainly controlled by the miner; only 15 per cent. of the coal output in 1922 was

cut by machine. Hence there should be great scope for further inquiries and for the adoption of methods of work determined scientifically. For example, the investigators considered the picks used, and found advantage came from using slightly heavier picks for coal than for harder material; while the question of using a comparatively large shovel for coal and a smaller one for heavy "dirt" was left for future research.

Pithead Baths

The miner at the end of his shift is black with coal dust, which gets beneath his clothes and soils his whole body; he is tired and his underclothes are cold and wet with perspiration. If the mine is a warm one, as is not unusual, when the miner is drawn to the surface he is on most days exposed to the chilling effect of a sudden alteration of temperature. No other group of workers have greater need for an opportunity for bathing and changing into dry clothes before traveling home.

The need is well recognized in other countries. Throughout Germany the provision and use of baths at collieries is, for the most part, obligatory. In Belgium a decree imposing on mine owners the provision of baths came into force in 1913, but long before that time baths existed and were so popular that miners left collieries without them for collieries provided with them. In France provision of bathing accommodation is compulsory for the larger mines. In New Zealand again the provision is compulsory. In the United States of America the value of wash and change houses both for coal and metalliferous miners is appreciated. The law in seven mining states calls for them to be provided, while in thirteen other states voluntary action has led to their fairly general adoption—indeed in these latter states some of the best accommodation is to be found. The United States Bureau of Mines has issued a series of reports describing the plants in existence and illustrating them by good plans; attention is therein drawn to the way in which shower baths refresh both mind and body, remove the effects of physical fatigue, and conduce to health.

> Good health and strong morale among the employees of any industry are to-day recognized as important factors in the maintenance of a high standard of production. In the mining industry, sanitary change and wash houses increase the efficiency of the miners . . . . (17, p. 1).

Many technical reasons have been advanced to explain the high output of American coal miners as compared with British. May not provision of baths be added to the list?

In Great Britain in 1922, when 921,737 persons were employed underground, there existed bathing facilities for less than 4,000 miners (18, p. 169). No explanations with regard to costs and to the Mines Acts can abolish this fact.

The case for pithead baths is unanswerable. They are required in the interests of efficiency and health; of absenteeism which is higher in wet weather for lack of change rooms; of the self-respect of the miner, who is avoided in train and tram by people in clean clothing—a matter of no small import to his psychology; and, not least, of the miner's wife. She has been busy before the miner returns,

preparing meals and boiling water (19, pp. 10–12):

> Sometimes the meal precedes the bath; sometimes it follows. Sometimes one man bathes while the others eat. The bath is taken in the kitchen—the popular living-room—on the hearth, in front of a large fire. The man divests himself of all his garments and washes himself in a wooden tub or a galvanized iron pan, while the family sit around or busy themselves with their ordinary domestic duties. Sometimes the wife or daughter assists the menfolk by scrubbing their backs. . . . . Nor is the preparation of the baths the heaviest burden that the system imposes upon the women. The bathing is followed by the clearing up, the putting away of the bathing utensils, the scouring of the floor, and, worst of all, the cleaning and drying of the men's clothes. The latter task, especially on a wet day, is irksome and unhealthy. The clothes are often soaking, and covered with mud and coaldust. They soil everything they touch. The wet and dirty garments must be dried and sometimes mended, and the big fires which have been prepared for boiling the water have to be maintained or renewed. The clothes are hung on the oven doors, or on clothes horses, or over chairs, wherever they can benefit from the heat of the fire.

Nor is the whole tale yet told; children get scalded by falling accidentally into the tubs of hot water prepared for the miner, and a coroner has written (19, pp.13–14):

> I have no hesitation in saying that hundreds of children have lost their lives during the last ten years through scalds at home. Is not this another argument in favour of pithead baths? *Every winter I hold more inquests on miners' children who die from scalds or burns than I do on miners who are killed underground;* yet while Government Inspectors are doing their best to safeguard the latter, the former are practically unprotected.

Wonder may be expressed that the call for pithead baths is not more insistent from within the industry. The owners do not move, looking upon them as unremunerative expenditure and not perceiving their productive value; the men, owing to their natural conservatism, are only half-hearted in support. Possibly, the offer to allocate money for the purpose from the Miners' Welfare Fund may prove some incentive (20) (21).

The next subject considered is also influenced by the absence of pithead baths.

Alcoholism

The miner now leaves the pit; soiled with the color-bar of his occupation; tired after work, a tiredness accentuated by his poor food supply; thirsty from losing more fluid by perspiration than he has had drink to replace; his clothes cold and damp with sweat. His tired body calls for a sedative, for fluid and for warmth. Alcohol is a sedative; it is consumed diluted with water; it is to be procured in a warm bar parlor. Hence, an alcoholic beverage is the ideal to meet his present need, even though far from being a future blessing. There is no reason to look further for an explanation of why the coal miner has justly earned a reputation for "convivial" drinking. The fact is brought out by examining the records of convictions in 1911 for drunkenness per square mile in the counties of England and Wales. Middlesex, it is true, stands top, doubtless owing to its unique position with regard to the city of London; but it is followed by Durham (6.15); Glamorgan (6.13); Yorkshire, West Riding

(3.62); Lancashire (3.32); Northumberland (2.37); Staffordshire (2.29); and Derbyshire (2.19). The existence of large coal fields is the characteristic common to each of these seven counties, which stand well above all the rest for convictions.

The miner is not an "industrial" drinker. No alcohol can be obtained after going below; when the effect of a dose taken before commencing work passes off, another dose cannot be obtained. The resulting effect is so unpleasant that the miner holds he cannot do his work on alcohol, and, for the most part, takes none until the day's work is over.

Herein, he differs from such men as dock laborers, who throughout the day have recourse to refreshers. Mortality records indicate that industrial drinking—*i.e.*, drinking before and during work—is far more harmful than convivial drinking; thus, all coal miners in England and Wales, 1910 to 1912, experienced a comparative mortality figure due to alcoholic diseases of only 9, while that for dock laborers was 30, and that for all males, 17.

The English coal fields are arranged in the lists which follow below according to mortality from alcoholic diseases in 1910 to 1912, and according to the average depth of the workings in 1922. Since the period 1910 to 1912 the mines in South Wales have been deepened below those in Lancashire; the transposition of these two fields is, therefore, not a matter of importance. As to the rest, if the positions of Nottingham and of Northumberland with Durham were transposed, the orders arrived at would be identical. Probably the similarity shown by these two orders is not entirely a chance one, and the suggestion arises that the provision of drinking water underground might have considerable effect in lessening convivial drinking among coal miners. Convivial drinking may not be so directly harmful as industrial drinking, but it accounts the next day for diminished capacity for work and, perhaps, for bad timekeeping. The suggestion has already been made that suitable drinking water underground would diminish fatigue, increase productivity, and abolish cramp.

Comparative Mortality, 1910 to 1912, for Alcoholic Diseases

Lancashire	12
Monmouth and South Wales	10
Yorkshire	9
Northumberland and Durham	9
Derbyshire	8
Nottingham	4

Average Depth of Workings, 1922,[1] *in Feet*

Monmouth and South Wales	1,650
Lancashire	1,500
Yorkshire	1,220
Nottingham	1,220
Derbyshire	922
Durham and Northumberland	800

Social Environment

Fertility

Our miner has now left work, and there remain for consideration his social life and environment. There is general agreement that his home surroundings are unsatisfactory; the miner's cottage is not an ideal residence. On many coal fields, the mining population constitutes the bulk of the local population and forms an isolated and specialized community.

A study of infant life in a community

[1] Staffordshire is omitted because the wide variation in the depth of the workings renders any average quite unreliable.

J. I. H.
May, 1925

TABLE 5.—OCCUPATIONAL GROUPS ARRANGED ACCORDING TO FERTILITY FIGURES

GROUP	SAMPLES OF GROUP	TOTAL FERTILITY FIGURE
First (least fertile) 10 per cent	barristers	165
	doctors	169
	solicitors	173
	clergy	184
Second 10 per cent	grocers	203
	wool spinners	209
	musicians	217
	cotton weavers	220
Third 10 per cent	police	234
	barbers	243
	milk sellers	246
	publicans	248
Fourth 10 per cent	printers	254
	tram drivers	257
	carpenters	262
	plumbers	263
Fifth 10 per cent	coach-makers	268
	coal dealers	271
	hosiery-makers	271
	greengrocers	280
Sixth 10 per cent	tailors	286
	cycle-makers	289
	cabinet-makers	290
	messengers, porters	292
Seventh 10 per cent	railway laborers	301
	iron molders	306
	bootmakers	308
	masons	312
Eighth 10 per cent	coopers	320
	potters	325
	quarrymen	327
	boiler-makers	328
Ninth 10 per cent	fishermen	330
	brick-makers	339
	navvies	345
	cutlers	346
Tenth (most fertile) 10 per cent	shipyard laborers	373
	pig iron workers	376
	coal heavers	381
	dock laborers	398

brings out at once the effects of occupation and of social status. The coal miner is found (22) with an unusually high total fertility as measured by the number of children born. He shares this position with other occupations involving heavy manual labor, and the conclusion may be drawn that output of physical energy is conducive to fertility.

Investigation also establishes an inverse relation between social status and fertility. The higher the status, the lower the fertility. Closely associated with these questions of social status and manual labor, comes the deduction that "broadly speaking, there seems to be an inverse relation between brain work and fertility." Some idea of the way in which total fertility varies in different classes can be obtained from the data given in Table 5.

The coal mining industry provides useful material for exemplifying these points. A special study has been made of the fertility of the miner in the county of Glamorgan, South Wales, as contrasted with that of agricultural laborers in rural districts and textile operatives in Lancashire and Yorkshire (see Table 6). The total

TABLE 6.—COMPARISON OF THE FERTILITY OF AGRICULTURISTS, TEXTILE WORKERS, AND MINERS IN CERTAIN LOCALITIES WITH THAT OF THE REMAINING POPULATION IN THE SAME LOCALITIES

	TOTAL FERTILITY		CHILD MORTALITY PER THOUSAND BORN	EFFECTIVE FERTILITY	
	Children Born per Hundred Couples	Ratios to England and Wales		Children Surviving per Hundred Couples	Ratios to England and Wales
Agriculturists[1]	307	109	123	270	116
Rest of population	280	99	122	246	106
Textile workers[2]	240	85	230	185	79
Rest of population	246	87	213	194	83
Coal miners[3]	341	121	217	267	115
Workers at the face	347	123	216	272	117
Others below ground	336	119	220	262	113
Workers above ground	314	111	210	248	107
Rest of population	292	103	176	240	103

[1] The rural districts of Lincolnshire, Norfolk, Suffolk, Cambridgeshire, and the Isle of Ely have been chosen to represent agriculture.

[2] The county boroughs of Blackburn, Bradford, Burnley, Dewsbury, Huddersfield, Oldham, and Rochdale represent the cotton and woolen industries (Lancashire and Yorkshire).

[3] Glamorganshire represents coal mining.

fertility of the miner is higher than that of the agriculturist and of the textile worker. It is higher than that of the population among which he lives; the same is true for the agriculturist who also performs heavy manual work; but not for the textile worker whose manual work is certainly not greater than that of the surrounding population.

TABLE 7.—FERTILITY AND CHILD MORTALITY IN ENGLAND AND WALES IN RELATION TO HUSBAND'S OCCUPATION (CHILDREN BORN AND CHILDREN SURVIVING PER HUNDRED COUPLES)

HUSBAND'S OCCUPATION	TOTAL FERTILITY (CHILDREN BORN PER HUNDRED COUPLES)	CHILD MORTALITY PER THOUSAND BORN	EFFECTIVE FERTILITY (CHILDREN SURVIVING PER HUNDRED COUPLES)
Coal and shale miners:			
Workers at the face	442	214	325
Other workers below ground	419	210	316
Workers above ground	396	207	308
Owners, agents, managers	338	143	309
Iron miners, quarriers	420	177	335
Stone miners, quarriers	393	170	322

Fertility within mining groups is highest where work is heaviest—*i.e.*, at the coal face—even though the earnings of the coal getter are, on the whole, higher than for the other two groups, a fact which might have been expected to lower his fertility by raising the social standing. Social grades, however, while of course they exist, are not so pronounced in a mining community as elsewhere; hence wages beyond a certain limit do not connote money expended on improved hygiene, but possibly the reverse. Certainly, if child mortality be taken as a measure of hygiene, the lowest paid group (workers above ground) are found with the lowest child mortality. This fact also holds good for all coal miners (see Table 7).

Data for the whole coal mining population of England and Wales exhibit the same variations and show, in addition, that the fertility of owners, agents, and managers is lower than that of manual workers. Other miners also show similar high fertility; hence the material worked cannot be the controlling factor.

The way in which child mortality modifies the advantages gained by high total fertility may be gathered from data for effective fertility. Here the coal miner, owing to a high child mortality (possibly due to lack of maternal care owing to the toil already mentioned exacted from the miner's wife), is found to have given way to the agriculturist, while the textile worker with an even higher child mortality (probably due to the industrial employment of women) has fallen even farther behind. Already much is being done to reduce the mortality,

particularly in South Wales, where in one mining district of Glamorgan an infant mortality rate of 158 twenty years ago has fallen to 86.

satisfaction prevailed on the different coal fields. The results are shown in Table 8; the orders of the fields so given on the three occasions are

TABLE 8.—RESULTS OF STRIKE BALLOTS OF THE MINERS TAKEN IN DIFFERENT BRITISH COAL FIELDS

COAL FIELD[1]	PERCENTAGE OF MINERS THAT VOTED		
	For Strike August, 1920	Against Resuming Work June, 1921	Against Wage Agreement January, 1924
Nottinghamshire	55.1	53.7	69.2
Derbyshire	71.8	52.7	76.8
Northumberland and Durham	69.9	66.7	75.9
Yorkshire	51.1	65.3	75.1
South Wales	77.9	73.0	89.8
Lancashire	90.6	89.6	94.3

[1] Separate ballot figures were not published for Staffordshire, so that composite field is excluded.

Mortality and Psychology

Reference has already been made to variations exhibited by mortality rates of miners employed on different coal fields. These variations which distinguish one field from another have existed for many years; they are caused largely by differences in mortality rates from four main causes of death: phthisis, pneumonia, bronchitis, and accidents.

An opinion is often voiced that contentment with life varies directly with health, and dissatisfaction with ill-being. Mortality may be held to be the final end of ill-being and to be some measure of its existence and so of the existence of the dissatisfaction it generates.

Ballots were taken of the miners of Great Britain on three recent occasions; they may be regarded as direct indications of the extent to which dis-

curiously alike. Lancashire always leads and South Wales is always second, while Nottinghamshire (with the exception of 1920 noted below) stands on each occasion at the bottom. The similarity of the orders as obtained by the ballots, and the close similarity found (see Tables 3 and 8) between them and the orders as obtained by mortality records, can hardly be chance occurrences.

One interesting apparent exception in the order of 1920, according to ballot, should be noted: Yorkshire is clearly out of the position which mortality records ascribe to it. But on this field a stike occurred in 1919 which did not involve other coal fields, and the effect of this event was held to modify the votes cast for the strike in 1920. In 1921 and 1924 when all the coal fields started from the same basis, the percentage vote indicative of dissatisfaction places Yorkshire much

more nearly in the order according to mortality records for 1910 to 1912.

Some of the conditions which lead to ill-being, ill health, and mortality among coal miners have already been discussed. Here is found evidence that these things influence the mind of the miner, and are at the back of that industrial unrest which tends too frequently to express itself in the economic disaster of a strike.

The way to remedy this psychology, with its results so paralyzing to the community, is to alter the conditions which give rise to it so that ill-being and ill health are reduced to a minimum. Indications have already been given of some means which may be employed to this end.

Miners' Welfare

A further means, even though it deals more with the welfare of the mining community than with the miner at work, already exists in the Miners' Welfare Fund, which is raised from a levy of one penny on every ton of coal raised. Since the tonnage of coal raised in the United Kingdom amounts to some 240,000,000 tons per annum, the fund receives about £1,000,000 per year (20). The purposes on which money may be expended are for the social well-being, recreation, and conditions of living of workers in or about coal mines, and for mining education and research; but in no case can it be expended for the building or repairing of dwelling houses.

This levy was made obligatory for five years by the British Mining Industry Act, 1920, and it seems probable that, owing to the excellent results which have been attained, the levy will become a permanency. The machinery for dealing with the fund consists of (*a*) a district committee for each coal field, composed of duly elected men and employers; on large coal fields, such as South Wales, there may also be several local subcommittees; and (*b*) a central committee, which allocates funds at the request of the district committees. Four-fifths of the levy has to be expended on the coal field whence it is raised; one-fifth is allocated entirely at the discretion of the central committee for matters of general mining interest, such as technical research into safety and health and higher education.

This fund raised from the industry for the industry forms a landmark in industrial welfare. The administrative machinery is now in full working order and by Dec. 31, 1923, grants on behalf of 602 schemes put forward by district committees had been allocated, amounting in all to £1,556,500, of which close to £1,000,000 was allocated during the previous twelve months. The money actually paid out by them amounted to £757,100 (21).

The schemes include 265 for recreation grounds and playing fields; 251 for institutes, clubs and libraries; 23 for assistance to hospitals; 23 for ambulance services; 11 for convalescent homes; 10 for district nursing services; 10 for pithead baths; and 9 for mining education. Meanwhile, research work is being financed and extensive schemes for its furtherance and for higher education are being worked out and will shortly be launched.

The effect of these varied activities on the mining community cannot but be great, and is already reported to be manifest, but years must elapse before

full benefit can accrue or the value of the fund be in any way measured.

Conclusion

The items of information just summarized present the picture of a considerable section of the industrial world—a fertile group of people by reason of their energy output—working under conditions which are capable of betterment. Their food supply during working hours could be improved, with a resulting improvement in efficiency. There is need for suitable drinking water to replace what is lost as sweat, and to lessen the tendency to convivial drinking. Better illumination is required in order to abolish nystagmus. The use of knee pads, especially in thin seams, would reduce the prevalence of beat knee, and attention to pick handles would reduce that of beat hand. Further investigation into the effect of inhaling dusts is required. Personal education on accident causation would lessen this cause of lost time and mortality. First-aid appliances and rescue stations should be placed under medical supervision. Instruction in how to work would lessen fatigue and increase output. Pithead baths would benefit the well-being and morale of the miners. In spite of these numerous possibilities for improvement, the occupation of coal mining is not, on the whole, an unhealthful one; but the mind of the miner is affected by such things as those discussed and expresses itself in a tendency to strike.

Only on one side today is an effort being made to rectify the miner's life—on the side of social welfare. Here much is being done; but more—much more—remains yet to do.

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BOOKS RECEIVED

Books received are acknowledged in this column, and such acknowledgment must be regarded as a sufficient return for the courtesy of the sender. Selections will be made for review in the interest of our readers and as space permits.

CONCEALED TUBERCULOSIS OR "THE TIRED SICKNESS." By *George Douglas Head*, B.S., M.D. Cloth. Pp. ix, 137 with index. Philadelphia: P. Blakiston's Son & Co., 1924.

INTERNATIONAL CLINICS. Volume I. Thirty-Fifth Series, 1925. Cloth. Pp. 301 with illustrations and index. Philadelphia and London: J. B. Lippincott Company, 1925.

PROCEEDINGS OF THE INTERNATIONAL CONFERENCE ON HEALTH PROBLEMS IN TROPICAL AMERICA. Held at Kingston, Jamaica, B.W.I., July 22 to August 1, 1924, by Invitation of the Medical Department, United Fruit Company. Cloth. Pp. xxi, 1010. Boston: United Fruit Company, 1924.

THE ESSENTIALS OF HEALTHFUL LIVING. By *William S. Sadler*, M.D., F.A.C.S., Formerly Professor at the Post Graduate Medical School of Chicago; Fellow of the American College of Surgeons; Senior Attending Surgeon to Columbus Hospital; Director of the Chicago Institute of Research and Diagnosis; Fellow of the American Medical Association; Member of the Chicago Medical Society, the Illinois State Medical Society, the American Public Health Association, etc. Cloth. Pp. xiv, 481 with index. New York: The Macmillan Company, 1925.

BOOK REVIEW

A PRESENT-DAY CONCEPTION OF MENTAL DISORDERS. By *Charles Macfie Campbell*, M.D., Professor of Psychiatry, Harvard University. Harvard Health Talks, 12. Cloth. Pp. 54. Cambridge: Harvard University Press, 1924.

This book presents the substance of a lecture delivered the past year by Dr. Campbell as one of a series of health talks expressly intended for the laity and sponsored by the Medical School of Harvard University. The style is unusually clear and is free from scientific terminology which is so apt to bewilder the uninitiated lay mind. There is, however, no loss of scientific truth in Dr. Campbell's attempt to make the lecture easily understood by his lay listeners. In fact, the initiated disciple of mental hygiene or psychiatry will find his time profitably spent in reading this book.

Dr. Campbell begins with this introductory statement: "This lecture proposes to deal with human nature working under difficulties, and to choose one small portion of that broad problem. I should like to interest you in some facts rather than in words, in a sample of the real stuff of human life rather than in the traditional and threadbare phrases with which we too often disguise the actual world, giving ourselves a pleasing illusion of knowledge. I ask you, therefore, to consider our topic to be not

'mental disorders,' but men, women, and children in difficulty, suffering, hoping, thwarted, groping."

Dr. Campbell then proceeds to dispel the taboo surrounding the word "mental," particularly when used together with "disorder." He argues for the same sane attitude toward these disorders as is now generally held toward physical disorder. Briefly, but adequately, he explains and illustrates a number of types of mild mental disorder.

On pages 27 to 50 there is a remarkable and interesting exposition of Dr. Campbell's philosophic and scientific attitude toward mental disorder. He passes quickly but with no sacrifice of clarity from a discussion of ultimates, free will, mind and matter, to such topics as the physiology and pathology of the central nervous system, instinctive level, conditioned reflexes, primitive mentality, magical and animistic thinking, childhood reactions and attitudes, and the pathology of the situation.

The following paragraph is too fundamental, too important to omit from this review. Its importance lies particularly in the fact that the truth expressed has been neglected too many times in our industrial programs where efficiency has been the guiding principle.

"Clear, logical thought has not always been the dominating factor in human behavior; and even in the most intellectual and emancipated individual it exercises less complete control than is usually supposed. Beneath the level of our clear conscious adult thought are childhood attitudes and feelings, residuals from the earlier phases of our own personal development; and beneath that level are indications of the same modes of human thought, which led primitive man to his conception of the forces of nature, with animistic and magical interpretations. At a still deeper level are those fundamental tendencies of great biological value, which we have in common with the animals, the instincts. The animal has an instinctive curiosity, but in primitive man the horizon of this curiosity begins to be greatly enlarged; and as human nature has developed, the search for knowledge has come to recognize no limits. Man's restless mind goes back to the beginning of time and to the extremity of space. He is not content to trace sequences, to establish laws of nature; he has eaten of the fruit of the Tree of Knowledge; he has to give values to things; he is not content with the *what* and the *how* of the phenomena, he wishes to know the *why* of his experience. Not content merely to register impressions and to forecast phenomena, he is forced to place his limited personal experience, with all its problems, on the background of some cosmic scheme, which his imagination constructs in response to an inner need. In his constructions we see a dual function of the mind, a subjective and an objective aspect."

Dr. Campbell summarizes his lecture by stating the following:

"*First:* to all who personally, or vicariously in relatives, have suffered from these disorders, it is a great relief to look upon them simply and directly as human ailments, to be studied like other ailments, to be treated in the same considerate manner as other ailments, to be talked of in the same

unembarrassed way in which we talk of other ailments.

"*Second:* a modern attitude to these ailments means that at the earliest indication of trouble, when treatment has most chance of being useful, these patients will be encouraged to seek advice, where there are available suitable facilities for diagnosis and treatment.

"*Third:* a community, which has emancipated itself from mediaeval views on these matters and from too narrow laboratory conceptions of disease, will realize that suitable facilities for diagnosis and treatment must be as abundantly supplied for these disorders as for other ailments, and will supply the funds necessary for that intensive medical research without which little progress can be expected.

"*Fourth:* the light thrown on the everyday problems of human life by those experiments, which nature makes when she produces a mental disorder, illuminates many of the problems of the school, of the home, of the factory and the store, and should contribute much of a constructive nature to social organization."—*Henry B. Elkind.*